

SUPPLEMENTAL GROUNDWATER
SAMPLING AND ANALYSIS
NATURAL ATTENUATION EVALUATION

ECKENFELDER INC.

Docket Number 450850

**SUPPLEMENTAL GROUNDWATER
SAMPLING AND ANALYSIS
NATURAL ATTENUATION EVALUATION**

Prepared for:

**MERITOR
Grenada, Mississippi**

Prepared by:

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January 1999

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January 20, 1999

27-60380.001

Mr. John Bozick
Environmental Engineer
Facilities Administration
Meritor Automotive, Inc.
2135 West Maple Road
Troy, MI 48084

Dear John:

Enclosed are two copies of the Supplemental Groundwater Sampling and Natural Attenuation Evaluation for the Textron site in Grenada, Mississippi.

Thank you for this opportunity to offer our services. Please call if you have any questions.

Sincerely,

Brown and Caldwell

Gregory L. Christians P.G.
Project Manager
Hydrogeology

Robert D. Norris, Ph.D.
Technical Director
Bioremediation Services

Attachments

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1.0 INTRODUCTION

Eckenfelder/Brown and Caldwell has prepared this report to discuss the results of additional groundwater sampling and analysis at the Randall Textron facility in Grenada, Mississippi. As discussed during our March 24, 1998 meeting, 14 groundwater monitoring wells (see Table 1-1) were sampled and analyzed for volatile organic compounds (VOCs), total chromium, and hexavalent chromium. The groundwater data were tabulated and comparisons were made with the previously collected data.

Additionally, six of the 14 monitoring wells were sampled and analyzed for bioremediation parameters. These results were used to provide a limited evaluation of the site for the possible use of intrinsic remediation as a remedial option. The evaluation provides a combination of direct and indirect qualitative information. This evaluation, though limited, provides a preliminary understanding of the intrinsic remediation (monitored natural attenuation) process at the site, and could aid in the selection of interim remedial actions. If intrinsic remediation is selected and recommended to MDEQ as a component of a remedial alternative, a more detailed evaluation and report would most likely be required by the MDEQ.

The primary objectives of the study were to assess current groundwater quality (VOC, and chromium distributions); determine whether VOC and chromium concentrations are increasing, decreasing, or remaining essentially constant; conduct a preliminary evaluation of natural attenuation; and provide an indication of which remedial technologies might be considered for the site.

TABLE 1-1

**MONITORING WELLS SAMPLED
MERITOR, GRENADA, MISSISSIPPI**

Well Name	Analysis		Bioremediation Parameters
	Total/Hexavalent Chromium	VOC's	
MW-1	X	X	
MW-2	X	X	X
MW-4	X	X	
DW-4	X	X	
MW-5	X	X	X
MW-6	X	X	
MW-10	X	X	X
MW-12	X	X	X
MW-14	X	X	X
MW-15	X	X	
MW-16	X	X	
MW-17	X	X	X
MW-23	X	X	
RT-5	X	X	

2.0 FIELD ACTIVITIES

During October 1998, 14 groundwater monitoring wells (see Table 1-1) were sampled and analyzed for volatile organic compounds (VOCs), total chromium, and hexavalent chromium. The groundwater data was tabulated and comparisons were made with the previously collected data. Additionally, six of the 14 monitoring wells were sampled and analyzed for bioremediation parameters (see Table 2-1). These results were used to provide a limited evaluation of the site for the potential use of intrinsic remediation as a component of a remedial alternative. Monitoring wells MW-3, MW-7 and MW-21 were to be sampled as part of the proposed scope of work. Monitoring well MW-3 was found to be dry. A considerable effort was made to locate MW-7, a flush-mounted well. However, due to the overgrowth of the area the well could not be located. The area adjacent to and around MW-21 has been recently logged. Due the amount of debris associated with this, access to MW-21 was not obtained. Monitoring well MW-12 was selected to replace MW-21.

Prior to groundwater sampling, all site monitoring wells and piezometers were measured to determine the depths to groundwater. Wells were then purged such that a minimum of three standing well volumes were removed. Clean latex gloves were donned before purging each well, and changed before collecting each sample. A dedicated bailer or a dedicated electric submersible pump with a polyethylene discharge tube was used to purge the individual wells. All purging and sampling equipment (pumps, tubing, bailers) was decontaminated prior to initial use by washing in phosphate-free detergent and triple rinsing with deionized, organic-free water. During purging, temperature, specific conductance, and pH of the water were monitored and recorded. Groundwater samples were collected when these parameters stabilized to within approximately plus or minus 10 percent of the two previous readings. This ensured that representative formation water was introduced to the well bore. Purge water for each monitoring well were contained in properly labeled DOT approved drums.

TABLE 2-1

BIOPARAMETERS FOR EVALUATION OF INTRINSIC REMEDIATION

Electron Acceptors and By-Products

Dissolved Oxygen^a
Nitrate/Nitrite
Manganese (total)
Manganese (II)^a
Iron (total)
Iron (II)^a
Sulfate
Sulfide^a
Carbonate/Bicarbonate
Carbon Dioxide^a
Methane

Other Degradation Parameters^b

VOCs
Ethene/Ethane
Volatile Fatty Acids
Nutrients
Phosphate (total)
TKN
Ammonium
Nitrate/Nitrite

Geochemical Parameters

pH^a
ORP (Eh)^a
Temp.^a
Conductivity^a

^aField measurements.

^bIncludes electron donors, nutrients, and degradation byproducts.

Samples were collected in containers supplied by the laboratory. Each sample was appropriately preserved in the field depending upon analytical requirements. All samples were stored on ice, at 4°C in coolers, and shipped to the ECKENFELDER INC. laboratory in Nashville, Tennessee. Standard chain-of-custody procedures were adhered to for sample transfer. Proper temperature control of the sample coolers was monitored in the field and upon receipt in the laboratory by including temperature control blanks in the sample coolers.

In addition to the sampling activities listed above, additional sample volumes were collected from the six monitoring wells listed in Table 1-1 and analyzed for the bioparameters listed in Table 2-1.

3.0 GROUNDWATER QUALITY

3.1 VOLATILE ORGANIC COMPOUNDS

The results of chemical analyses are provided in Table 3-1 for VOCs. Table 3-2 shows historic concentrations for TCE in selected wells. Laboratory reports and field data sheets are presented in Appendix A.

The primary VOC constituents observed in groundwater were trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE), and vinyl chloride. Toluene, ethylbenzene, and xylenes were present in the sample collected from MW-2. Lesser concentrations of other chlorinated organics including 1,1-dichloroethane (1,1-DCA), 1,1-dichloroethene (1,1-DCE) and trans-1,2-dichloroethene (trans-1,2-DCE) were present in low concentrations in some wells. cis-1,2-DCE and vinyl chloride are the primary degradation intermediates of TCE while 1,1-DCE and trans-1,2-DCE are minor degradation products of TCE.

In general the groundwater quality has not changed significantly from the historical data. High concentrations of TCE, cis-1,2-DCE, and vinyl chloride persist. Some details are noteworthy. TCE concentrations in samples collected from MW-5, located near the drainage ditch approximately 150 feet from the stream, have shown a steady increase as follows:

<u>Year</u>	<u>TCE (µg/L)</u>
1993	15,000
1996	51,000
1998	100,000

The adjacent well, MW-10, which is screened deeper, 42 feet BGS vs. 15 feet BGS for MW-5, has continued to be only moderately impacted by TCE at 4 to 6.5 µg/L (all J qualified).

TABLE 3-1

RESULTS FOR DETECTED VOCs
MERITOR, GRENADA, MISSISSIPPI

Well Name	Date	Trichloro-ethene		cis-1,2-Dichloro-ethene	Vinyl chloride	Acetone	Benzene	Bromo-dichloro-methane	Carbon disulfide	1,1-Dichloro-ethane
		1	10							
		MDL	EQL	UNITS	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
MW-1	10/6/98		UD	62000 D	1200 D	UD	UD	UD	UD	UD
MW-2	10/6/98	650000 D		170000 D	6600 D	UD	UD	UD	UD	UD
MW-4	10/5/98	3700 D		16000 D	3200 D	U	2.8 J	U	5.7 J	U
DW-4	10/5/98	20000 D		5700 D	1200 D	U	9.2 J	U	U	44
MW-5	10/6/98	100000 D		37000 D	200 JD	UD	UD	UD	UD	UD
MW-5 Dupe	10/6/98	99000 D		36000 D	200 JD	UD	UD	UD	UD	UD
MW-6	10/5/98	2900 D		20000 D	18000 D	30 J	1.5 J	U	2 J	U
MW-10	10/6/98	6.5 JD		UD	UD	UD	UD	UD	UD	UD
MW-12	10/8/98	22		190	U	U	U	U	U	U
MW-14	10/6/98	1200 D		500 D	UD	UD	UD	UD	UD	UD
MW-15	10/6/98	5200 D		2300 D	7.8 J	U	U	U	U	U
MW-16	10/5/98	2800 D		3700 D	360	U	U	U	U	U
MW-17	10/6/98	13000 D		2800 D	310 JD	UD	UD	UD	UD	UD
MW-23	10/6/98	200 D		95 D	11 JD	UD	UD	UD	UD	UD
RT-5	10/6/98	10000 D		6100 D	180 JD	UD	UD	UD	UD	UD

TABLE 3-1

RESULTS FOR DETECTED VOCs
MERITOR, GRENADA, MISSISSIPPI

Well Name	Date	1,1-Dichloro-ethene	trans-1,2-Dichloro-ethene	Ethylbenzene	Methylene chloride	Tetra-chloro-ethene	Toluene	Xylene-(total)
	MDL	1	1	1	1	1	1	1
	EQL	10	10	10	10	10	10	10
	UNITS	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
MW-1	10/6/98	UD	470 JD	100 JD	UD	UD	UD	UD
MW-2	10/6/98	250 JD	UD	380 JD	UD	80 JD	2200 D	1200 D
MW-4	10/5/98	36	78	14	U	5.5 J	82	34
DW-4	10/5/98	37	27	U	6.2 J	54	U	2.8 J
MW-5	10/6/98	UD	240 JD	UD	UD	UD	UD	UD
MW-5 Dupe	10/6/98	UD	UD	UD	UD	UD	UD	UD
MW-6	10/5/98	32	38	13	U	U	160	59
MW-10	10/6/98	UD	UD	UD	UD	UD	UD	UD
MW-12	10/8/98	U	U	U	U	U	U	U
MW-14	10/6/98	UD	UD	UD	UD	UD	UD	UD
MW-15	10/6/98	10	5.2 J	U	U	12	U	U
MW-16	10/5/98	12	16	U	U	6.1 J	U	U
MW-17	10/6/98	UD	UD	UD	UD	UD	UD	UD
MW-23	10/6/98	UD	3.3 JD	UD	UD	UD	UD	UD
RT-5	10/6/98	UD	UD	UD	UD	UD	UD	UD

TABLE 3-2

TRICHLOROETHENE CONCENTRATION COMPARISON
MERITOR, GRENADA, MISSISSIPPI

Year Sampled	MW-2 (ug/L)	MW-4 (ug/L)	MW-5 (ug/L)	MW-6 (ug/L)	MW-10 (ug/L)	MW-14 (ug/L)	MW-16 (ug/L)	MW-17 (ug/L)	DW-4 (ug/L)
1998	650,000 D	3,700 D	100,000 D	2,900 D	6.5 J	1,200 D	2,800 D	13,000 D	20,000 D
1996	41,000 D	3,600 D	51,000 D	160	4 J	1,100 D	3,600 D	12,000 D	28,000 D
1993	690,000 D	3,500 JD	15,000 D	9,000 JD	5.1 J	380 D	7,100 D	11,000 D	NS
	480,000 JD	3,900 D	12,000 D	2,700 D	2.3 J	330 D	5,500 D	12,000 D	
	560,000 D	2,900 D	15,000 D	9,800 D				11,000 D	

NS - Not Sampled

D - sample was diluted.

J - estimated result.

Monitoring well MW-14 is the furthest downgradient monitoring well, and is located close to the where the drainage ditch discharges to the stream. The concentration of TCE in the most recent sample was 1,200 µg/L compared to 1,100 µg/L in 1996 and 380 µg/L in 1993.

Thus for the three wells located in the downgradient portion of the plume, TCE levels appear to have increased in two wells, and remained constant in the least impacted well.

The highest concentrations of TCE is still found in MW-2 at 650,000 µg/L or approximately one-half the solubility limit. DNAPL was observed at the base of MW-2. TCE in the adjacent well, MW-17, remains essentially constant at approximately 12,000 µg/L.

The concentration of TCE in MW-6 was approximately twenty times the concentration reported in 1996 but similar to that reported in 1993.

TCE concentrations in wells MW-4, DW-4, MW-16 and MW-17 were virtually the same in 1998 as in 1996 and in 1993 (except for DW-4, which was not sampled in 1993).

Overall, the TCE concentrations within the aquifer have remained fairly constant, the apparent increase in TCE in MW-5 is noteworthy because the well is located near the surface water discharge. The concentrations of cis-1,2-DCE and vinyl chloride also substantially elevated in this well.

Concentrations of organic compounds that exceed one percent of their solubility limit are considered potential indication of free phase organics or for TCE, the presence of DNAPL. The solubility limit for TCE is 1,100 mg/L or 1,100,000 µg/L. For TCE concentrations in groundwater exceeding 11,000 µg/L, one can anticipate the presence of DNAPL at or upgradient to that location. The reported concentrations of TCE for wells MW-2, MW5, DW-4, and MW-17 exceed 1 percent of the solubility limit for TCE

suggesting the widespread occurrence of DNAPL. DNAPL was collected from well MW-2 during this sampling event.

3.2 CHROMIUM ANALYSIS

The results of the chromium analyses are provided in Table 3-3. Also presented on this table is a comparison to historic chromium concentrations collected during the 1993 RI. Both total chromium and hexavalent chromium were collected from 14 monitoring wells. Total chromium was detected in six of fourteen samples. The detected concentrations ranged from 0.020 mg/L to 3.6 mg/L, with the highest concentrations observed in samples from wells DW-4, MW-6, and RT-5. Total chromium concentrations were observed to significantly increase as compared to the historic 1993 results in monitoring wells MW-6, MW-15, MW-23, and RT-5. Hexavalent chromium was detected in three samples. The detected ranged from 0.25 mg/L to 3.0 mg/L, with the highest results being observed in DW-4 (3.0 mg/L) and RT-5 (1.4 mg/L). The concentrations are consistent with those observed during the RI with the exception of RT-5, which showed an increase from non-detection to 1.4 mg/L. No historical results are available for comparison for DW-4. Laboratory reports and field data sheets are presented in Appendix A.

TABLE 3-3

CHROMIUM RESULTS
MERITOR, GRENADA, MISSISSIPPI

Well Name	Date	Chromium Total (1998) mg/L	Chromium Total (1993) mg/L	Chromium Hexavalent (1998) mg/L	Chromium Hexavalent (1993) mg/L
MW-1	10/06/98	U	0.0043	U	U
MW-2	10/06/98	U	U	U	U
MW-4	10/05/98	U	U	U	U
DW-4	10/05/98	3.6	NA	3.0	NA
MW-5	10/06/98	U	U	U	U
MW-5 Dupe	10/06/98	U	U	U	U
MW-6	10/05/98	2.3	0.011	U	U
MW-10	10/06/98	U	U	U	U
MW-14	10/06/98	U	U	U	0.05/U
MW-15	10/05/98	0.040	0.005	U	U
MW-16	10/05/98	0.020	0.062	U	U/0.060
MW-17	10/06/98	U	U	U	U
MW-12	10/08/98	U	U	U	U
MW-23	10/06/98	0.43	0.200/0.293	0.25	0.210/0.279
RT-5	10/06/98	1.5	0.027	1.4	U

U - not detected

NA - not analyzed

4.0 NATURAL ATTENUATION

As discussed in Appendix B, natural attenuation occurs as a result of several mechanisms. Physical mechanisms such as dispersion, diffusion, and adsorption occur within all aquifers resulting in dilution and retardation of the plume, but not in mass removal. Degradation, including reductive dechlorination of TCE, occurs in most but not all aquifers impacted by TCE. The EPA generally requires evidence of reductive dechlorination when chlorinated solvents are present in order to accept monitored natural attenuation as a component of a remedy. It is likely that monitored natural attenuation would not be acceptable to EPA as the sole remedy.

The first and most significant indicator that natural attenuation is of environmental benefit is whether the plume is expanding, relatively stable (dynamic equilibrium or steady state), or receding. As discussed earlier, TCE concentrations have been relatively constant since 1993 although concentrations of TCE observed in MW-5 appear to be increasing and are four orders of magnitude greater than the MCL for TCE.

Further, MW-5 is close to the ditch and relatively close to the stream. It is probable that VOCs are being discharged to the ditch and/or stream. Thus, while reductive dechlorination is occurring and appears to convert a substantial amount of TCE to its daughter products, it is probably not preventing discharge of VOCs to surface waters.

The most direct evidence of reductive dechlorination where TCE is the constituent introduced into the aquifer is the presence of cis-1,2-DCE, vinyl chloride, and ethene since these compounds would not have been directly introduced to the environment except, potentially, as low-concentration impurities in TCE. At this site, cis-1,2-DCE and vinyl chloride are present in most of the aquifer with the concentration of cis-1,2-DCE exceeding that of TCE at some locations. Clearly, reductive dechlorination occurs within the plant site aquifer.

That reductive dechlorination occurs is not sufficient justification to employ monitored natural attenuation. In fact, cis-1,2-DCE and vinyl chloride are more mobile than is TCE and vinyl chloride is a known carcinogen. To be acceptable to EPA, natural attenuation must prevent migration of all toxic components to receptors and prevent expansion of the plume.

Evaluation of bioparameters according to the Air Force Center for Environmental Excellence (AFCEE) as described in Appendices B and C provides additional support for reductive dechlorination having occurred at the site. Furthermore, the evaluation of bioparameter data provides an indication of the appropriateness of current site conditions for continued natural attenuation.

The bioparameter data shown in Table 4-1 have been evaluated with respect to whether the aquifer geochemistry provides evidence of ongoing reductive dechlorination. First, the AFCEE protocol was used to rank the site as summarized in Table 4-2. Points are awarded based either on values of certain parameters, or by comparisons of plume values to background values. Well MW-12 was used as the background well, although it has been impacted by low levels of VOCs. Well MW-21 was initially selected as a background well, but was not accessible.

As shown in Table 4-3, the individual wells in the plume were scored resulting in totals ranging from 6 to 20 points. Table 4-4 shows the interpretation guide from the AFCEE protocol. The interpretation of the evidence for reductive dechlorination is considered strong for MW-17; adequate for MW-2 and MW-5; and limited for MW-10 and MW-14.

Since one or more wells provided strong evidence of reductive dechlorination, the guidance suggests that further evaluation of natural attenuation is warranted.

Typically, fate and transport modeling could be conducted for the site. However, it would be difficult to apply a fate and transport model with the existing site data because of the limited number of wells located along the same flow path. This is evident by considering

TABLE 4-1
BIOREMEDIATION PARAMETERS
MERITOR, GRENADA, MISSISSIPPI

Well Name		Iron mg/L	Manganese mg/L	Alkalinity		Ammonia (as N), Non-Distilled mg/L	Nitrate+ Nitrite (as N) mg/L		Phosphorus Total (as P) mg/L	Sulfate mg/L	TKN mg/L	Volatile Fatty Acids mg/L
				Bicarbonate (as CaCO ₃) mg/L	Carbonate (as CaCO ₃) mg/L							
MW-2	10/06/98	4.0	U	64	U	0.13	U	U	0.10	36	0.48	24
MW-5	10/06/98	U	0.16	40	U	U	U	U	0.033	55	U	14
MW-5 Dup.	10/06/98	U	0.15	35	U	U	U	U	0.028	53	U	7.5
MW-10	10/06/98	1.6	0.30	56	U	0.11	U	U	0.058	21	U	5.8
MW-14	10/06/98	U	0.0020	41	U	U	U	U	0.066	18	U	U
MW-17	10/06/98	5.2	0.32	60	U	0.17	U	U	0.10	87	U	2.9
MW-12	10/08/98	180	53	58	U	U	1.8	U	0.15	23	U	4.8

Field Parameters

Well Name		Dissolved		Iron mg/L	Carbon		Hydrogen		ORP mV
		Oxygen mg/L	Manganese mg/L		Dioxide mg/L	Sulfide mg/L			
MW-2	10/06/98	<0.2	0.1	3.5	190	0	0	126	
MW-5	10/06/98	0.4	0.1	0	150	0	0	281	
MW-5 Dup.	10/06/98	0.4	0	0	155	0	0	281	
MW-10	10/06/98	0.4	0.1	1.4	45	0	0	236	
MW-14	10/06/98	1.2	0	0.1	55	0	0	320	
MW-17	10/06/98	<0.2	0.1	4.3	45	0	0	180	
MW-12	10/08/98	2.2	0	0.1	45	0	0	190	

U - not detected

TABLE 4-2

ANALYTICAL PARAMETERS AND WEIGHTING
FOR PRELIMINARY SCREENING OF NATURAL ATTENUATION
USEPA/AFCEE PROTOCOL

Analyte	Concentration in Most Contaminated Zone	Interpretation	Points Awarded
Oxygen ^a	< 0.5 mg/L	Tolerated, suppresses reductive dechlorination at higher concentrations	3
Oxygen ^a	> 5 mg/L	Vinyl chloride may be oxidized aerobically, but reductive dechlorination will not occur	-3
Nitrate ^a	< 1 mg/L	May compete with reductive pathway at higher concentrations	2
Iron (II) ^a	> 1 mg/L	Reductive pathway possible	3
Sulfate ^a	< 20 mg/L	May compete with reductive pathway at higher concentrations	2
Sulfide ^a	> 1 mg/L	Reductive pathway possible	3
Methane ^a	> 0.1 mg/L	Ultimate reductive daughter product	2
Methane ^a	> 1 mg/L	Vinyl chloride accumulates	3
Methane ^a	< 1 mg/L	Vinyl chloride oxidizes	--
Oxidation reduction potential ^a	< 50 mV against Ag/AgCl < -100 mV	Reductive pathway possible Reductive pathway possible	1 2
pH ^a	5 < pH < 9	Tolerated range for reductive pathway	--
DOC	> 20 mg/L	Carbon and energy source; drives dechlorination; can be natural or anthropogenic	2
Temperature ^a	> 20°C	At T > 20°C, biochemical process is accelerated	1
Carbon dioxide	> 2 x background	Ultimate oxidative daughter product	1
Alkalinity	> 2 x background	Results from interaction of carbon dioxide with aquifer minerals	1
Chloride ^a	> 2 x background	Daughter product of organic chlorine; compare chloride in plume to background conditions	2
Hydrogen	> 1 nM	Reductive pathway possible; vinyl chloride may accumulate	3
Hydrogen	< 1 nM	Vinyl chloride oxidized	--

TABLE 4-2 (Continued)

ANALYTICAL PARAMETERS AND WEIGHTING
FOR PRELIMINARY SCREENING OF NATURAL ATTENUATION
USEPA/AFCEE PROTOCOL

Analyte	Concentration in Most Contaminated Zone	Interpretation	Points Awarded
Volatile fatty acids	> 0.1 mg/L	Intermediates resulting from biodegradation of aromatic compounds; carbon and energy source	2
BTEX ^a	> 0.1 mg/L	Carbon and energy source; drives dechlorination	2
Perchloroethene ^a	--	Material released	--
Trichloroethene ^a	--	Material released or daughter of product of perchloroethene	2 ^b
Dichloroethene ^a	--	Material released or daughter product of trichloroethene; if amount of cis-1,2-dichloroethene is greater than 80 percent of total dichloroethene, it is likely a daughter product of trichloroethene	2 ^b
Vinyl chloride ^a	--	Material released or daughter product of dichloroethenes	2 ^b
Ethene/Ethane	> 0.01 > 0.1	Daughter product of vinyl chloride/ethene Daughter product of vinyl chloride/ethene	2 3
Chloroethane ^a	--	Daughter product of vinyl chloride under reducing conditions	2
1,1,1-Trichloroethane ^a	--	Material released	--
1,1-dichloroethene ^a	--	Daughter product of trichloroethene or chemical reaction of 1,1,1-trichloroethane	--

^aRequired analysis.^bPoints awarded only if it can be shown that the compound is a daughter product (i.e., not a constituent of the source NAPL).

TABLE 4-3

USEPA/AFCEE SCREENING FOR NATURAL ATTENUATION FOR REDUCTIVE DECHLORINATION
MERITOR
GRENADA, MISSISSIPPI

Parameter	Background MW-12	MW-2	Attenuation Point Score	MW-5	Attenuation Point Score	MW-10	Attenuation Point Score	MW-14	Attenuation Point Score	MW-17	Attenuation Point Score
Oxygen	2.2	0.1	3	0.4	3	0.4	0	1.2	0	0.1	3
Nitrate	1.8	0	2	0	2	0	2	0	2	0	2
Iron	0.1	3.5	3	0	0	1.4	3	0.1	0	4.3	3
Manganese	0	0.1	0	0.1	0	0.1	0	0	0	0.1	0
Sulfate	23	36	0	54	0	21	0	18	2	87	0
Sulfide	0	0	0	0	0	0	0	0	0	0	0
Methane	NA	1	0	0.005	0	0	0	0	0	0	3
Eh (ORP)	190	126	0	281	0	236	0	320	0	180	0
BTEX/KETONES											
TOC	NA	0	0	0	0	0	0	0	0	0.043	0
Carbon Dioxide	45	190	1	153	1	45	0	55	0	45	0
Alkalinity	58	64	0	37	0	56	0	41	0	60	0
Chloride	NA	NA	0	0	0	0	0	0	0	0	0
VOA Fatty Acids	4.8	24	2	11	2	5.8	2	0	0	2.9	2
PCE	NA	NA	0	NA	0	NA	0	NA	0	NA	0
TCE	22	650,000	0	100,000	0	6.5	0	1,200	0	13,000	0
cis-DCE	190	170,000	2	37,000	2	0	0	500	2	2,800	2
Vinyl Chloride	0	6,600	2	200	2	0	0	0	0	310	2
Ethene/Ethane	ND	420	3	1.2	3	0	0	0	0	0.004	0
Chloroethene	ND	0	0	NA	0	NA	0	NA	0	NA	2
1,1,1-TCA	ND	0	0	NA	0	NA	0	NA	0	NA	2
1,1-DCE	ND	NA	0	NA	0	NA	0	NA	0	NA	0
Score Total:			20		15		7		6		21

(a) Measurement suspect no points awarded

TABLE 4-4

**INTERPRETATION OF POINTS AWARDED DURING
SCREENING PROCESS FOR NATURAL ATTENUATION^a**

Score	Interpretation
0 to 5	Inadequate evidence for biodegradation of chlorinated organics
6 to 14	Limited evidence for biodegradation of chlorinated organics
15 to 20	Adequate evidence for biodegradation of chlorinated organics
>20	Strong evidence for biodegradation of chlorinated organics

^aRefer to AFCEE Proposed Protocol for Natural Attenuation in Appendix B.

the TCE concentrations in MW-2, MW-5, and MW-14, which are 650,000 µg/L, 100,000 µg/L, and 1,200 µg/L, respectively. The relative difference in TCE concentrations in MW-5 and MW-14 is too large for these two wells to be on the same flow path.

We have performed a few simple calculations that provide an extremely rough estimate of apparent attenuation and degradation rates based on MW-2 and MW-5, being perhaps, on or close to the same flow path. These only serve as a crude indication of whether the apparent changes in TCE concentrations along a flow path are consistent with the range of degradation rates observed at other sites. Where the answer is yes, it does not preclude other mechanisms.

The crude apparent attenuation rates due to all mechanisms were obtained by application of the following formulas:

$$\frac{dC}{dt} = kt \quad (\text{Eq. 1})$$

where:

C = concentration at time t [M/L³]

k = overall attenuation rate (first-order rate constant) [1/T]

Solving this differential equation yields:

$$C = C_0 e^{-kt}$$

The contribution to the apparent attenuation rate due to degradation is calculated by accounting for the effects of dispersion and retardation using the following equation. This assumes a first order decay process.

$$\lambda = \frac{v_c}{4\alpha_x} \left(\left[1 + 2\alpha_x \left(\frac{k}{v_x} \right) \right]^2 - 1 \right) \quad (\text{Eq. 2})$$

where:

- λ = first-order biological decay rate
- v_c = retarded contaminant velocity in the x-direction
- α_x = dispersivity
- k/v_x = slope of line formed by making a log-linear plot of contaminant concentration versus distance downgradient along the flow path

The first column in Table 4-5 indicates the well pairs, the second and third columns are the apparent attenuation rates based on all mechanisms, and the fourth and fifth columns are the apparent contribution to attenuation resulting from degradation.

The apparent attenuation rates are due largely to degradation (presumably reductive dechlorination) as seen by comparing column 5 to column 3. The estimated degradation rate for the MW-2/MW-5 pair is 0.80 years^{-1} , equivalent to a half-life of 0.87 years. This is about the average observed at other sites.

In summary, the qualitative observations, the AFCEE protocol ranking results, and the rough attenuation rate calculations are consistent with reductive dechlorination occurring at the site. These observations are also consistent with the on-going discharge of VOC impacted groundwater to the stream.

5.0 IMPLICATIONS FOR REMEDIATION

The site data suggest on-going reductive dechlorination, which that requires reducing conditions. Both TCE and its degradation products and chromium (VI) are present in groundwater. DNAPL is present in the vicinity of MW-2 and, possibly, in other locations. Remediation at the site should, ideally, address the plume(s), but also the source areas.

Complete remediation of DNAPL is difficult to achieve as some residual DNAPL is likely to remain and serve as a continuing source of impact to groundwater. However, in situ remediation techniques that could be considered for addressing DNAPL include surfactant flushing, chemical oxidation (e.g., permanganate), and in-situ thermal enhanced extraction.

Since reducing conditions exist within the plume and since TCE, its daughter products, and chromium (III) can be addressed by a number of processes that generate and rely on reducing conditions, these types of remediation technologies should receive serious consideration for addressing the plume. These technologies include addition of readily degraded organic matter (electron donors) such as lactic acid, molasses, or a hydrogen source; addition of sodium dithionite solution; and mixing of fine iron particles into the soil matrix. Natural attenuation of portions of the plume is particularly compatible with these technologies.

Evaluation of a remedy for the site should also take into account the potential decommissioning of the sludge lagoon. A feasibility study is needed to evaluate remedial options and develop a site strategy.

APPENDIX A

**LABORATORY REPORTS
AND FIELD DATA SHEETS**



Client: Meritor #60380
 Date Sampled: 10/06/98
 Date Received: 10/07/98
 Date Reported: 10/21/1998

ECKENFELDER SAMPLE NUMBER			V2BLK1015	V1BLK1016	V1BLK1019	9810048-01	9810048-02D	9810048-03D
CLIENT SAMPLE DESCRIPTION			M.BLANK	M.BLANK	M.BLANK	Trip Blank #1117	RT-5	MW-23
VOLATILE ORGANICS BY USEPA METHOD 8260			MDL	EQL	CONC	CONC	CONC	CONC
							50 X(1) CONC	2.0 X(1) CONC
Acetone	5.0	50	U	U	U	U	U D	U D
Benzene	1.0	10	U	U	U	U	U D	U D
Bromodichloromethane	1.0	10	U	U	U	U	U D	U D
Bromoform	1.0	10	U	U	U	U	U D	U D
Bromomethane	2.0	20	U	U	U	U	U D	U D
2-Butanone	10	100	U	U	U	U	U D	U D
Carbon disulfide	1.0	10	U	U	U	U	U D	U D
Carbon tetrachloride	1.0	10	U	U	U	U	U D	U D
Chlorobenzene	1.0	10	U	U	U	U	U D	U D
Chloroethane	2.0	20	U	U	U	U	U D	U D
Chloroform	1.0	10	U	U	U	U	U D	U D
Chloromethane	2.0	20	U	U	U	U	U D	U D
Dibromochloromethane	1.0	10	U	U	U	U	U D	U D
1,1-Dichloroethane	1.0	10	U	U	U	U	U D	U D
1,2-Dichloroethane	1.0	10	U	U	U	U	U D	U D
1,1-Dichloroethene	1.0	10	U	U	U	U	U D	U D
cis-1,2-Dichloroethene	1.0	10	U	U	U	U	6100 D	95 D
trans-1,2-Dichloroethene	1.0	10	U	U	U	U	U D	3.3 JD
1,2-Dichloropropane	1.0	10	U	U	U	U	U D	U D
cis-1,3-Dichloropropene	1.0	10	U	U	U	U	U D	U D
trans-1,3-Dichloropropene	1.0	10	U	U	U	U	U D	U D
Ethylbenzene	1.0	10	U	U	U	U	U D	U D
2-Hexanone	2.0	20	U	U	U	U	U D	U D
Methylene chloride	1.0	10	U	U	U	U	U D	U D
4-Methyl-2-pentanone	2.0	20	U	U	U	U	U D	U D
Styrene	1.0	10	U	U	U	U	U D	U D
1,1,2,2-Tetrachloroethane	1.0	10	U	U	U	U	U D	U D
Tetrachloroethene	1.0	10	U	U	U	U	U D	U D
Toluene	1.0	10	U	U	U	U	U D	U D
1,1,1-Trichloroethane	1.0	10	U	U	U	U	U D	U D
1,1,2-Trichloroethane	1.0	10	U	U	U	U	U D	U D
Trichloroethene	1.0	10	U	U	U	U	10000 D	200 D
Vinyl chloride	2.0	20	U	U	U	U	180 JD	11 JD
Xylene(total)	1.0	10	U	U	U	U	U D	U D

ALL COMPOUNDS EXPRESSED IN MICROGRAMS/LITER UNLESS OTHERWISE NOTED.

SEE ATTACHED PAGE FOR DEFINITIONS OF TERMS AND QUALIFIERS.

(1) = SAMPLES WERE DILUTED BY THE NUMERICAL VALUE DISPLAYED.
 DETECTION LIMITS SHOULD INCREASE BY THE SAME FACTOR.

227 French Landing Drive
 Nashville, Tennessee 37228
 615.255.2288
 FAX 615.256.8332

ECKENFELDER INC.®

Client: Meritor #60380
 Date Sampled: 10/06/98
 Date Received: 10/07/98
 Date Reported: 10/21/1998

ECKENFELDER SAMPLE NUMBER			9810048-04D	9810048-04D	9810048-05D	9810048-06D	9810048-06D	9810048-07D
CLIENT SAMPLE DESCRIPTION			MW-1	MW-1	MW-14	MW-2	MW-2	MW-5
VOLATILE ORGANICS			50 X(1)	500 X(1)	10 X(1)	50 X(1)	5000 X(1)	50 X(1)
BY USEPA METHOD 8260	MDL	EQL	CONC	CONC	CONC	CONC	CONC	CONC
Acetone	5.0	50	U D	U D	U D	U D	U D	U D
Benzene	1.0	10	U D	U D	U D	U D	U D	U D
Bromodichloromethane	1.0	10	U D	U D	U D	U D	U D	U D
Bromoform	1.0	10	U D	U D	U D	U D	U D	U D
Bromomethane	2.0	20	U D	U D	U D	U D	U D	U D
2-Butanone	10	100	U D	U D	U D	U D	U D	U D
Carbon disulfide	1.0	10	U D	U D	U D	U D	U D	U D
Carbon tetrachloride	1.0	10	U D	U D	U D	U D	U D	U D
Chlorobenzene	1.0	10	U D	U D	U D	U D	U D	U D
Chloroethane	2.0	20	U D	U D	U D	U D	U D	U D
Chloroform	1.0	10	U D	U D	U D	U D	U D	U D
Chloromethane	2.0	20	U D	U D	U D	U D	U D	U D
Dibromochloromethane	1.0	10	U D	U D	U D	U D	U D	U D
1,1-Dichloroethane	1.0	10	U D	U D	U D	U D	U D	U D
1,2-Dichloroethane	1.0	10	U D	U D	U D	U D	U D	U D
1,1-Dichloroethene	1.0	10	U D	U D	U D	250 JD	U D	U D
cis-1,2-Dichloroethene	1.0	10	64000 DE	62000 D	500 D	130000 DE	170000* D	37000 D
trans-1,2-Dichloroethene	1.0	10	470 JD	570 JD	U D	U D	U D	240 JD
1,2-Dichloropropane	1.0	10	U D	U D	U D	U D	U D	U D
cis-1,3-Dichloropropene	1.0	10	U D	U D	U D	U D	U D	U D
trans-1,3-Dichloropropene	1.0	10	U D	U D	U D	U D	U D	U D
Ethylbenzene	1.0	10	100 JD	U D	U D	380 JD	U D	U D
2-Hexanone	2.0	20	U D	U D	U D	U D	U D	U D
Methylene chloride	1.0	10	U D	U D	U D	U D	U D	U D
4-Methyl-2-pentanone	2.0	20	U D	U D	U D	U D	U D	U D
Styrene	1.0	10	U D	U D	U D	U D	U D	U D
1,1,2,2-Tetrachloroethane	1.0	10	U D	U D	U D	U D	U D	U D
Tetrachloroethene	1.0	10	U D	U D	U D	80 JD	U D	U D
Toluene	1.0	10	U D	U D	U D	2200 D	U D	U D
1,1,1-Trichloroethane	1.0	10	U D	U D	U D	U D	U D	U D
1,1,2-Trichloroethane	1.0	10	U D	U D	U D	U D	U D	U D
Trichloroethene	1.0	10	U D	U D	1200 D	490000 DE	650000* D	99000 DE
Vinyl chloride	2.0	20	1200 D	1300 JD	U D	6600 D	U D	200 JD
Xylene(total)	1.0	10	U D	U D	U D	1200 D	U D	U D

ALL COMPOUNDS EXPRESSED IN MICROGRAMS/LITER UNLESS OTHERWISE NOTED.

SEE ATTACHED PAGE FOR DEFINITIONS OF TERMS AND QUALIFIERS.

(1) = SAMPLES WERE DILUTED BY THE NUMERICAL VALUE DISPLAYED.
 DETECTION LIMITS SHOULD INCREASE BY THE SAME FACTOR.

* = DILUTION VOLUME HAD TO BE TAKEN FROM A PREVIOUSLY OPENED VIAL.
 RESULTS SHOULD BE CONSIDERED AS ESTIMATED.

ECKENFELDER INC.®

Client: Meritor #60380
 Date Sampled: 10/06/98
 Date Received: 10/07/98
 Date Reported: 10/21/1998

ECKENFELDER SAMPLE NUMBER				9810048-07D	9810048-08D	9810048-09D	9810048-11	9810048-12	9810048-13D
CLIENT SAMPLE DESCRIPTION				MW-5	MW-10	MW-17	EB-1	Trip Blank #1118	MW-5 Dupe
VOLATILE ORGANICS				500 X(1)	2.0 X(1)	50 X(1)			50 X(1)
BY USEPA METHOD 8260	MDL	EQL		CONC	CONC	CONC	CONC	CONC	CONC
Acetone	5.0	50		U D	U D	U D	U	U	U D
Benzene	1.0	10		U D	U D	U D	U	U	U D
Bromodichloromethane	1.0	10		U D	U D	U D	U	U	U D
Bromoform	1.0	10		U D	U D	U D	U	U	U D
Bromomethane	2.0	20		U D	U D	U D	U	U	U D
2-Butanone	10	100		U D	U D	U D	U	U	U D
Carbon disulfide	1.0	10		U D	U D	U D	U	U	U D
Carbon tetrachloride	1.0	10		U D	U D	U D	U	U	U D
Chlorobenzene	1.0	10		U D	U D	U D	U	U	U D
Chloroethane	2.0	20		U D	U D	U D	U	U	U D
Chloroform	1.0	10		U D	U D	U D	U	U	U D
Chloromethane	2.0	20		U D	U D	U D	U	U	U D
Dibromochloromethane	1.0	10		U D	U D	U D	U	U	U D
1,1-Dichloroethane	1.0	10		U D	U D	U D	U	U	U D
1,2-Dichloroethane	1.0	10		U D	U D	U D	U	U	U D
1,1-Dichloroethene	1.0	10		U D	U D	U D	U	U	U D
cis-1,2-Dichloroethene	1.0	10		40000 D	U D	2800 D	U	U	42000 DE
trans-1,2-Dichloroethene	1.0	10		U D	U D	U D	U	U	U D
1,2-Dichloropropane	1.0	10		U D	U D	U D	U	U	U D
cis-1,3-Dichloropropene	1.0	10		U D	U D	U D	U	U	U D
trans-1,3-Dichloropropene	1.0	10		U D	U D	U D	U	U	U D
Ethylbenzene	1.0	10		U D	U D	U D	U	U	U D
2-Hexanone	2.0	20		U D	U D	U D	U	U	U D
Methylene chloride	1.0	10		U D	U D	U D	U	U	U D
4-Methyl-2-pentanone	2.0	20		U D	U D	U D	U	U	U D
Styrene	1.0	10		U D	U D	U D	U	U	U D
1,1,2,2-Tetrachloroethane	1.0	10		U D	U D	U D	U	U	U D
Tetrachloroethene	1.0	10		U D	U D	U D	U	U	U D
Toluene	1.0	10		U D	U D	U D	U	U	U D
1,1,1-Trichloroethane	1.0	10		U D	U D	U D	U	U	U D
1,1,2-Trichloroethane	1.0	10		U D	U D	U D	U	U	U D
Trichloroethene	1.0	10		100000 D	6.5 JD	13000 D	U	U	100000 DE
Vinyl chloride	2.0	20		U D	U D	310 JD	U	U	200 JD
Xylene(total)	1.0	10		U D	U D	U D	U	U	U D

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SEE ATTACHED PAGE FOR DEFINITIONS OF TERMS AND QUALIFIERS.

(1) - SAMPLES WERE DILUTED BY THE NUMERICAL VALUE DISPLAYED.
 DETECTION LIMITS SHOULD INCREASE BY THE SAME FACTOR.

Client: Meritor #60380
Date Sampled: 10/06/98
Date Received: 10/07/98
Date Reported: 10/21/1998

ECKENFELDER INC.®

ECKENFELDER SAMPLE NUMBER			9810048-13D	
CLIENT SAMPLE DESCRIPTION			MW-5 Dupe	
VOLATILE ORGANICS			500 X(1)	
BY USEPA METHOD 8260			CONC	
	MDL	EQL		
Acetone	5.0	50	U	D
Benzene	1.0	10	U	D
Bromodichloromethane	1.0	10	U	D
Bromoform	1.0	10	U	D
Bromomethane	2.0	20	U	D
2-Butanone	10	100	U	D
Carbon disulfide	1.0	10	U	D
Carbon tetrachloride	1.0	10	U	D
Chlorobenzene	1.0	10	U	D
Chloroethane	2.0	20	U	D
Chloroform	1.0	10	U	D
Chloromethane	2.0	20	U	D
Dibromochloromethane	1.0	10	U	D
1,1-Dichloroethane	1.0	10	U	D
1,2-Dichloroethane	1.0	10	U	D
1,1-Dichloroethene	1.0	10	U	D
cis-1,2-Dichloroethene	1.0	10	36000*	D
trans-1,2-Dichloroethene	1.0	10	U	D
1,2-Dichloropropane	1.0	10	U	D
cis-1,3-Dichloropropene	1.0	10	U	D
trans-1,3-Dichloropropene	1.0	10	U	D
Ethylbenzene	1.0	10	U	D
2-Hexanone	2.0	20	U	D
Methylene chloride	1.0	10	U	D
4-Methyl-2-pentanone	2.0	20	U	D
Styrene	1.0	10	U	D
1,1,2,2-Tetrachloroethane	1.0	10	U	D
Tetrachloroethene	1.0	10	U	D
Toluene	1.0	10	U	D
1,1,1-Trichloroethane	1.0	10	U	D
1,1,2-Trichloroethane	1.0	10	U	D
Trichloroethene	1.0	10	99000*	D
Vinyl chloride	2.0	20	U	D
Xylene (total)	1.0	10	U	D

ALL COMPOUNDS EXPRESSED IN MICROGRAMS/LITER UNLESS OTHERWISE NOTED.

SEE ATTACHED PAGE FOR DEFINITIONS OF TERMS AND QUALIFIERS.

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DETECTION LIMITS SHOULD INCREASE BY THE SAME FACTOR.

* = DILUTION VOLUME HAD TO BE TAKEN FROM A PREVIOUSLY OPENED VIAL.
RESULTS SHOULD BE CONSIDERED AS ESTIMATED.

ECKENFELDER INC.

D. R. DAVIS

D. RICK DAVIS
VICE PRESIDENT/ANALYTICAL & TESTING SERVICES

ANALYTICAL REPORT TERMS AND QUALIFIERS (ORGANIC)

- MDL:** The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero. The MDL is determined from analysis of a sample containing the analyte in a given matrix.
- EQL:** The estimated quantitation limit (EQL) is defined as the estimated concentration above which quantitative results can be obtained with a specific degree of confidence. ECKENFELDER INC. defines the EQL to be ten times the MDL.
- U:** The presence of a "U" indicates that the analyte was analyzed for but was not detected or the concentration of the analyte quantitated below the MDL.
- B:** The presence of a "B" to the right of an analytical value indicates that this compound was also detected in the method blank and the data should be interpreted with caution. One should consider the possibility that the correct sample result might be less than the reported result and, perhaps, zero.
- D:** When a sample (or sample extract) is rerun diluted because one of the compound concentrations exceeded the highest concentration range for the standard curve, all of the values obtained in the dilution run will be flagged with a "D".
- E:** The concentration for any compound found which exceeds the highest concentration level on the standard curve for that compound will be flagged with an "E". Usually the sample will be rerun at a dilution to quantitate the flagged compound.
- J:** The presence of a "J" to the right of an analytical result indicates that the reported result is estimated. The mass spectral data pass the identification criteria showing that the compound is present, but the calculated result is less than the EQL. One should feel confident that the result is greater than zero and less than the EQL.



CLIENT: Meritor #60380

DATE RECEIVED: 10/07/98

DATE REPORTED: 10/23/98

ECKENFELDER SAMPLE NUMBER				9810048-02	9810048-03	9810048-04
CLIENT SAMPLE DESCRIPTION/SAMPLING DATE				RT-5 10/6/98 10:50:00 AM	MW-23 10/6/98 11:35:00 AM	MW-1 10/6/98 12:50:00 PM
ANALYTES	REPORTING LIMITS	USEPA METHOD	UNITS	CONC	CONC	CONC
Chromium, Total	0.0050	6010B	mg/L	1.5	0.43	U
Chromium, Hexavalent	0.13	7196A	mg/L	1.4	0.25	U

SEE ATTACHED PAGE FOR DEFINITION OF TERMS AND QUALIFIERS

ECKENFELDER INC.®**CLIENT: Meritor #60380****DATE RECEIVED: 10/07/98****DATE REPORTED: 10/23/98**

ECKENFELDER SAMPLE NUMBER				9810048-05	9810048-06
CLIENT SAMPLE DESCRIPTION/SAMPLING DATE				MW-14 10/6/98 1:35:00 PM	MW-2 10/6/98 2:24:00 PM
ANALYTES	REPORTING LIMITS	USEPA METHOD	UNITS	CONC	CONC
Chromium, Total	0.0050	6010B	mg/L	U	U
Chromium, Hexavalent	0.025	7196A	mg/L	U	U
Iron	0.10	6010B	mg/L	U	4.0
Manganese	0.0010	6010B	mg/L	0.0020	U
Alkalinity, Bicarbonate (as CaCO ₃)	1.0	2320B**	mg/L	41	64
Alkalinity, Carbonate (as CaCO ₃)	1.0	2320B**	mg/L	U	U
Ammonia (as N), Non-Distilled	0.10	350.3	mg/L	U	0.13
Nitrate+ Nitrite (as N)	0.10	353.2	mg/L	U	U
Phosphorus, Total (as P)	0.020	365.2	mg/L	0.066	0.10
Sulfate	1.0	9038	mg/L	18	36
TKN	0.20	351.2	mg/L	U	0.48
Volatile Fatty Acids (9)	2.0	5560C**	mg/L	U	24

SEE ATTACHED PAGE FOR DEFINITION OF TERMS AND QUALIFIERS

ECKENFELDER INC.®**CLIENT: Meritor #60380****DATE RECEIVED: 10/07/98****DATE REPORTED: 10/23/98**

ECKENFELDER SAMPLE NUMBER				9810048-07
CLIENT SAMPLE DESCRIPTION/SAMPLING DATE				MW-5 10/6/98 1:35:00 PM
ANALYTES	REPORTING LIMITS	USEPA METHOD	UNITS	CONC
Chromium, Total	0.0050	6010B	mg/L	U
Chromium, Hexavalent	0.025	7196A	mg/L	U
Iron	0.10	6010B	mg/L	U
Manganese	0.0010	6010B	mg/L	0.16
Alkalinity, Bicarbonate (as CaCO ₃)	1.0	2320B**	mg/L	40
Alkalinity, Carbonate (as CaCO ₃)	1.0	2320B**	mg/L	U
Ammonia (as N), Non-Distilled	0.10	350.3	mg/L	U
Nitrate+ Nitrite (as N)	0.10	353.2	mg/L	U
Phosphorus, Total (as P)	0.020	365.2	mg/L	0.033
Sulfate	2.0	9038	mg/L	55
TKN	0.20	351.2	mg/L	U
Volatile Fatty Acids (9)	2.0	5560C**	mg/L	14

SEE ATTACHED PAGE FOR DEFINITION OF TERMS AND QUALIFIERS

ECKENFELDER INC.®**CLIENT: Meritor #60380****DATE RECEIVED: 10/07/98****DATE REPORTED: 10/23/98**

ECKENFELDER SAMPLE NUMBER				9810048-08
CLIENT SAMPLE DESCRIPTION/SAMPLING DATE				MW-10 10/6/98 12:45:00 PM
ANALYTES	REPORTING LIMITS	USEPA METHOD	UNITS	CONC
Chromium, Total	0.0050	6010B	mg/L	U
Chromium, Hexavalent	0.025	7196A	mg/L	U
Iron	0.10	6010B	mg/L	1.6
Manganese	0.0010	6010B	mg/L	0.30
Alkalinity, Bicarbonate (as CaCO ₃)	1.0	2320B**	mg/L	56
Alkalinity, Carbonate (as CaCO ₃)	1.0	2320B**	mg/L	U
Ammonia (as N), Non-Distilled	0.10	350.3	mg/L	0.11
Nitrate+ Nitrite (as N)	0.10	353.2	mg/L	U
Phosphorus, Total (as P)	0.020	365.2	mg/L	0.058
Sulfate	1.0	9038	mg/L	21
TKN	0.20	351.2	mg/L	U
Volatile Fatty Acids (9)	2.0	5560C**	mg/L	5.8

SEE ATTACHED PAGE FOR DEFINITION OF TERMS AND QUALIFIERS

ECKENFELDER INC.®**CLIENT: Meritor #60380****DATE RECEIVED: 10/07/98****DATE REPORTED: 10/23/98**

ECKENFELDER SAMPLE NUMBER				9810048-09
CLIENT SAMPLE DESCRIPTION/SAMPLING DATE				MW-17 10/6/98 3:00:00 PM
ANALYTES	REPORTING LIMITS	USEPA METHOD	UNITS	CONC
Chromium, Total	0.0050	6010B	mg/L	U
Chromium, Hexavalent	0.025	7196A	mg/L	U
Iron	0.10	6010B	mg/L	5.2
Manganese	0.0010	6010B	mg/L	0.32
Alkalinity, Bicarbonate (as CaCO ₃)	1.0	2320B**	mg/L	60
Alkalinity, Carbonate (as CaCO ₃)	1.0	2320B**	mg/L	U
Ammonia (as N), Non-Distilled	0.10	350.3	mg/L	0.17
Nitrate+ Nitrite (as N)	0.10	353.2	mg/L	U
Phosphorus, Total (as P)	0.020	365.2	mg/L	0.10
Sulfate	4.0	9038	mg/L	87
TKN	0.20	351.2	mg/L	U
Volatile Fatty Acids (9)	2.0	5560C**	mg/L	2.9

SEE ATTACHED PAGE FOR DEFINITION OF TERMS AND QUALIFIERS

ECKENFELDER INC.®**CLIENT: Meritor #60380****DATE RECEIVED: 10/07/98****DATE REPORTED: 10/23/98**

ECKENFELDER SAMPLE NUMBER				9810048-11
CLIENT SAMPLE DESCRIPTION/SAMPLING DATE				EB-1 10/6/98 5:50:00 PM
ANALYTES	REPORTING LIMITS	USEPA METHOD	UNITS	CONC
Chromium, Total	0.0050	6010B	mg/L	U
Chromium, Hexavalent	0.025	7196A	mg/L	U
Iron	0.10	6010B	mg/L	U
Manganese	0.0010	6010B	mg/L	U
Alkalinity, Bicarbonate (as CaCO ₃)	1.0	2320B**	mg/L	U
Alkalinity, Carbonate (as CaCO ₃)	1.0	2320B**	mg/L	U
Ammonia (as N), Non-Distilled	0.10	350.3	mg/L	U
Nitrate+ Nitrite (as N)	0.10	353.2	mg/L	U
Phosphorus, Total (as P)	0.010	365.2	mg/L	U
Sulfate	1.0	9038	mg/L	U
TKN	0.20	351.2	mg/L	U
Volatile Fatty Acids (9)	2.0	5560C**	mg/L	2.9

SEE ATTACHED PAGE FOR DEFINITION OF TERMS AND QUALIFIERS

ECKENFELDER INC.®**CLIENT: Meritor #60380****DATE RECEIVED: 10/07/98****DATE REPORTED: 10/23/98**

ECKENFELDER SAMPLE NUMBER				9810048-13
CLIENT SAMPLE DESCRIPTION/SAMPLING DATE				MW-5 Dupe 10/6/98 12:00:00 PM
ANALYTES	REPORTING LIMITS	USEPA METHOD	UNITS	CONC
Chromium, Total	0.0050	6010B	mg/L	U
Chromium, Hexavalent	0.025	7196A	mg/L	U
Iron	0.10	6010B	mg/L	U
Manganese	0.0010	6010B	mg/L	0.15
Alkalinity, Bicarbonate (as CaCO ₃)	1.0	2320B**	mg/L	35
Alkalinity, Carbonate (as CaCO ₃)	1.0	2320B**	mg/L	U
Ammonia (as N), Non-Distilled	0.10	350.3	mg/L	U
Nitrate+ Nitrite (as N)	0.10	353.2	mg/L	U
Phosphorus, Total (as P)	0.020	365.2	mg/L	0.028
Sulfate	2.0	9038	mg/L	53
TKN	0.20	351.2	mg/L	U
Volatile Fatty Acids (9)	2.0	5560C**	mg/L	7.5

SEE ATTACHED PAGE FOR DEFINITION OF TERMS AND QUALIFIERS

ECKENFELDER INC.

**D. RICK DAVIS****VICE PRESIDENT/ANALYTICAL & TESTING SERVICES**

ANALYTICAL REPORT NOTES, TERMS AND QUALIFIERS (INORGANIC)

Notes:

The metals and cyanide reporting limits (RLs) have been statistically determined to be no less than 3 standard deviations as defined in 40 CFR 136, Appendix B, Revision 1.11. All other reporting limits are referenced from the specific analytical method.

Terms:

- NA Not Applicable
- NR Not Requested
- U Below Reporting Limits

Qualifiers:

- B The reported value is less than the practical quantitation limit (PQL, project defined) but greater than or equal to the RL.
- E The reported value is estimated due to the presence of matrix interference.
- N Predigested spike recovery not within control limits.
- W Post digestion spike recovery not within control limits.
- * RPD or absolute difference for Duplicate analysis not within control limits.
- ** Reference Standard Methods 17th edition.
- (1) pH analyzed outside USEPA specified holding time. pH must be measured immediately after sample collection.
- (2) The sample pH did not meet the preservation guidelines. Therefore the pH was adjusted upon receipt.
- (3) The sample had to be diluted because of matrix interferences.
- (4) Reference Standard Methods 17th edition for the distillation method.
- (5) The sample was analyzed out of the USEPA holding time.
- (6) The sample was received in the laboratory out of the USEPA holding time.
- (7) The shipping cooler temperature exceeded 6°C upon receipt to ECKENFELDER INC.
- (8) When the concentration of the analyte is below the detection limit, the detection limit must be divided by the %Solids (in decimal form) in order to obtain the sample's true detection limit on a dry weight basis.
- (9) Analysis was subcontracted




Client: Meritor #60380
Date Sampled: 10/08/98
Date Received: 10/09/98
Date Reported: 10/21/1998

ECKENFELDER SAMPLE NUMBER			V1BLK1016	9810080-01
CLIENT SAMPLE DESCRIPTION			M.BLANK	MW-12
VOLATILE ORGANICS BY USEPA METHOD 8260	MDL	EQL	CONC	CONC
Acetone	5.0	50	U	U
Benzene	1.0	10	U	U
Bromodichloromethane	1.0	10	U	U
Bromoform	1.0	10	U	U
Bromomethane	2.0	20	U	U
2-Butanone	10	100	U	U
Carbon disulfide	1.0	10	U	U
Carbon tetrachloride	1.0	10	U	U
Chlorobenzene	1.0	10	U	U
Chloroethane	2.0	20	U	U
Chloroform	1.0	10	U	U
Chloromethane	2.0	20	U	U
Dibromochloromethane	1.0	10	U	U
1,1-Dichloroethane	1.0	10	U	U
1,2-Dichloroethane	1.0	10	U	U
1,1-Dichloroethene	1.0	10	U	U
cis-1,2-Dichloroethene	1.0	10	U	190
trans-1,2-Dichloroethene	1.0	10	U	U
1,2-Dichloropropane	1.0	10	U	U
cis-1,3-Dichloropropene	1.0	10	U	U
trans-1,3-Dichloropropene	1.0	10	U	U
Ethylbenzene	1.0	10	U	U
2-Hexanone	2.0	20	U	U
Methylene chloride	1.0	10	U	U
4-Methyl-2-pentanone	2.0	20	U	U
Styrene	1.0	10	U	U
1,1,2,2-Tetrachloroethane	1.0	10	U	U
Tetrachloroethene	1.0	10	U	U
Toluene	1.0	10	U	U
1,1,1-Trichloroethane	1.0	10	U	U
1,1,2-Trichloroethane	1.0	10	U	U
Trichloroethene	1.0	10	U	22
Vinyl chloride	2.0	20	U	U
Xylene(total)	1.0	10	U	U

ALL COMPOUNDS EXPRESSED IN MICROGRAMS/LITER UNLESS OTHERWISE NOTED.

SEE ATTACHED PAGE FOR DEFINITIONS OF TERMS AND QUALIFIERS.

ECKENFELDER INC.


D. RICK DAVIS
VICE PRESIDENT/ANALYTICAL & TESTING SERVICES
225 Arch Creek Landing Drive
Nashville, Tennessee 37228
615.255.2288
FAX 615.256.8332

ANALYTICAL REPORT TERMS AND QUALIFIERS (ORGANIC)

- MDL:** The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero. The MDL is determined from analysis of a sample containing the analyte in a given matrix.
- EQL:** The estimated quantitation limit (EQL) is defined as the estimated concentration above which quantitative results can be obtained with a specific degree of confidence. ECKENFELDER INC. defines the EQL to be ten times the MDL.
- U:** The presence of a "U" indicates that the analyte was analyzed for but was not detected or the concentration of the analyte quantitated below the MDL.
- B:** The presence of a "B" to the right of an analytical value indicates that this compound was also detected in the method blank and the data should be interpreted with caution. One should consider the possibility that the correct sample result might be less than the reported result and, perhaps, zero.
- D:** When a sample (or sample extract) is rerun diluted because one of the compound concentrations exceeded the highest concentration range for the standard curve, all of the values obtained in the dilution run will be flagged with a "D".
- E:** The concentration for any compound found which exceeds the highest concentration level on the standard curve for that compound will be flagged with an "E". Usually the sample will be rerun at a dilution to quantitate the flagged compound.
- J:** The presence of a "J" to the right of an analytical result indicates that the reported result is estimated. The mass spectral data pass the identification criteria showing that the compound is present, but the calculated result is less than the EQL. One should feel confident that the result is greater than zero and less than the EQL.



CLIENT: Meritor #60380

DATE RECEIVED: 10/09/98

DATE REPORTED: 10/30/98

ECKENFELDER SAMPLE NUMBER				9810080-01
CLIENT SAMPLE DESCRIPTION/SAMPLING DATE				MW-12 10/8/98 4:30:00 PM
ANALYTES	REPORTING LIMITS	USEPA METHOD	UNITS	CONC
Chromium	5.0	6010B/200.7	µg/L	U
Chromium, Hexavalent	0.025	7196A	mg/L	U
Iron	100	6010B/200.7	µg/L	180
Manganese	1.0	6010B/200.7	µg/L	53
Alkalinity, Bicarbonate (as CaCO ₃)	1.0	2320B**	mg/L	58
Alkalinity, Carbonate (as CaCO ₃)	1.0	2320B**	mg/L	U
Ammonia, Non-Distilled (as N)	0.10	350.3	mg/L	U
Nitrate+ Nitrite (as N)	0.10	353.2	mg/L	1.8
Phosphorus, Total (as P)	0.020	365.2	mg/L	0.15
Sulfate	1.0	9038	mg/L	23
TKN	0.20	351.2	mg/L	U
Volatile Fatty Acids (9)	2.0	5560C**	mg/L	4.8

SEE ATTACHED PAGE FOR DEFINITION OF TERMS AND QUALIFIERS

ECKENFELDER INC.

Thomas M. Davis
For

D. RICK DAVIS

VICE PRESIDENT/ANALYTICAL & TESTING SERVICES

ANALYTICAL REPORT NOTES, TERMS AND QUALIFIERS (INORGANIC)

Notes:

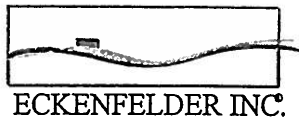
The metals and cyanide reporting limits (RLs) have been statistically determined to be no less than 3 standard deviations as defined in 40 CFR 136, Appendix B, Revision 1.11. All other reporting limits are referenced from the specific analytical method.

Terms:

NA	Not Applicable
NR	Not Requested
U	Below Reporting Limits

Qualifiers:

- | | |
|-----|--|
| B | The reported value is less than the practical quantitation limit (PQL, project defined) but greater than or equal to the RL. |
| E | The reported value is estimated due to the presence of matrix interference. |
| N | Predigested spike recovery not within control limits. |
| W | Post digestion spike recovery not within control limits. |
| * | RPD or absolute difference for Duplicate analysis not within control limits. |
| ** | Reference Standard Methods 17th edition. |
| (1) | pH analyzed outside USEPA specified holding time. pH must be measured immediately after sample collection. |
| (2) | The sample pH did not meet the preservation guidelines. Therefore the pH was adjusted upon receipt. |
| (3) | The sample had to be diluted because of matrix interferences. |
| (4) | Reference Standard Methods 17th edition for the distillation method. |
| (5) | The sample was analyzed out of the USEPA holding time. |
| (6) | The sample was received in the laboratory out of the USEPA holding time. |
| (7) | The shipping cooler temperature exceeded 6°C upon receipt to ECKENFELDER INC. |
| (8) | When the concentration of the analyte is below the detection limit, the detection limit must be divided by the %Solids (in decimal form) in order to obtain the sample's true detection limit on a dry weight basis. |
| (9) | Analysis was subcontracted |



ECKENFELDER INC.

CLIENT: Meritor # 60380.000

DATE SAMPLED: 10/6/98

DATE RECEIVED: 10/7/98

DATE REPORTED: 10/14/98

ECKENFELDER SAMPLE NUMBER		9810048-05	9810048-06	9810048-07	9810048-08
CLIENT SAMPLE DESCRIPTION		MW-14	MW-2 *	MW-5	MW-10
ANALYTES	DETECTION LIMITS	CONC	CONC	CONC	CONC
Methane	3.0	<3.0	1000	5.0	<3.0
Ethylene	1.0	<1.0	410	<1.0	<1.0
Ethane	1.0	<1.0	10	1.2	<1.0

ALL RESULTS EXPRESSED IN MICROGRAMS/LITER
UNLESS OTHERWISE NOTED.

SEE ATTACHED PAGE FOR DEFINITION OF TERMS AND QUALIFIERS.

* = ANALYSIS WAS SUBCONTRACTED.

ECKENFELDER INC.®**CLIENT: Meritor # 60380.000****DATE SAMPLED: 10/6/98, 10/8/98****DATE RECEIVED: 10/7/98, 10/9/98****DATE REPORTED: 10/14/98**

ECKENFELDER SAMPLE NUMBER		9810048-09	9810048-11	9810048-13	9810080-01
CLIENT SAMPLE DESCRIPTION		MW-17 *	EB-1	MW-5 Dupe	MW-12
ANALYTES	DETECTION LIMITS	CONC	CONC	CONC	CONC
Methane	3.0	43	<3.0	6.4	<3.0
Ethylene	1.0	1.9	<1.0	<1.0	<1.0
Ethane	1.0	1.9	<1.0	1.2	<1.0

ALL RESULTS EXPRESSED IN MICROGRAMS/LITER
UNLESS OTHERWISE NOTED.

SEE ATTACHED PAGE FOR DEFINITION OF TERMS AND QUALIFIERS.

* = ANALYSIS WAS SUBCONTRACTED.

ECKENFELDER INC.**D. RICK DAVIS****VICE PRESIDENT/ANALYTICAL & TESTING SERVICES**

ECKENFELDER INC.

GROUNDWATER SAMPLING FIELD DATA SHEET

LOCATION No. MW-1

SAMPLE No. _____

PROJECT: Meritor Supplemental Sampling

DATE: 10-6-98 TIME: 1250

CLIENT: Meritor (Rockwell) Grenada, MS

WEATHER CONDITIONS: Clear

JOB No: 60380.001

AIR TEMPERATURE: 80°

PERSONNEL: S. Williams / R. Guidry

WELL DATA:

CASING, DIAMETER: 2" ☐ STAINLESS STEEL ☐ STEEL ☒ PVC ☐ TEFLON ☐ OTHER: _____

INTAKE, DIAMETER: 2" ☐ STAINLESS STEEL ☐ GALV. STEEL ☒ PVC ☐ TEFLON ☐ OPEN ROCK

STATIC WATER LEVEL: 12.66 BOTTOM DEPTH: 16.5

DATUM: ☐ TOP OF PROT. CASING ☒ TOP OF WELL CASING ☐ OTHER: _____

WELL CLEAN TO BOTTOM? ☒ YES ☐ NO WELL IN GOOD CONDITION ☒ YES ☐ NO

VOLUME OF WATER IN WELL: 0.7 gal

PURGING DATA:

METHOD: ☐ BLADDER PUMP ☒ PERISTALTIC PUMP ☐ BAILER ☐ SUB. PUMP ☐ OTHER: _____

MATERIALS: PUMP / BAILER: ☐ TEFLON ☐ STAINLESS STEEL ☐ PVC ☒ OTHER: Tygon

TUBING / ROPE: _____

☐ TEFLON ☐ POLYPROPYLENE ☐ NYLON ☒ OTHER: LDPE

PUMPING RATE: < 0.3 gpm ELAPSED TIME: _____ VOLUME PUMPED: 2.1 gal

WAS WELL EVACUATED? ☐ YES ☒ NO NUMBER OF WELL VOLUMES PURGED: 3

TIME SERIES DATA: WELL VOLUMES 1 2 3

TEMP _____

pH 6.9 7.0 7.0

SPEC COND. 830 840 840

PURGING EQUIPMENT: ☒ DEDICATED ☐ PREPARED OFF-SITE ☐ FIELD CLEANED

SAMPLING DATA:

METHOD: ☐ BLADDER PUMP ☐ PERISTALTIC PUMP ☒ BAILER ☐ OTHER: _____

MATERIALS: PUMP / BAILER: ☒ TEFLON ☐ STAINLESS STEEL ☐ PVC ☐ OTHER: _____

TUBING / ROPE: _____

☐ TEFLON ☐ POLYPROPYLENE ☒ NYLON ☐ OTHER: _____

SAMPLING EQUIPMENT: ☒ DEDICATED ☐ PREPARED OFF-SITE ☐ FIELD CLEANED

METALS SAMPLE FIELD FILTERED? ☐ YES ☒ NO METHOD: NA

PHYSICAL & CHEMICAL DATA:

APPEARANCE: ☒ CLEAR ☐ TURBID ☐ COLOR: _____

☐ CONTAINS IMMISCIBLE LIQUID ☐ OTHER: _____

FIELD DETERMINATIONS: TEMP: _____ pH: 7.0 SPEC. COND: 840

I CERTIFY THAT THIS SAMPLE WAS COLLECTED AND HANDLED IN ACCORDANCE WITH APPLICABLE REGULATORY AND CORPORATE PROTOCOLS

SIGNATURE _____

DATE 10-6-98

ECKENFELDER
INC.

GROUNDWATER SAMPLING
FIELD DATA SHEET

LOCATION No. MW-3

SAMPLE No. _____

PROJECT: Meritor Supplemental Sampling

DATE: 10-6-98

TIME: _____

CLIENT: Meritor (Rockwell) Grenada, MS

WEATHER CONDITIONS: _____

JOB No: 60380.001

AIR TEMPERATURE: _____

PERSONNEL: S. Williams / R. Guidry

Well not Sampled / No H₂O

WELL DATA:

CASING, DIAMETER: 2" ☐ STAINLESS STEEL ☐ STEEL ☒ PVC ☐ TEFLON ☐ OTHER: _____

INTAKE, DIAMETER: 2" ☐ STAINLESS STEEL ☐ GALV. STEEL ☒ PVC ☐ TEFLON ☐ OPEN ROCK

STATIC WATER LEVEL: _____ BOTTOM DEPTH: 11.1

DATUM: ☐ TOP OF PROT. CASING ☒ TOP OF WELL CASING ☐ OTHER: _____

WELL CLEAN TO BOTTOM? ☒ YES ☐ NO WELL IN GOOD CONDITION ☒ YES ☐ NO

VOLUME OF WATER IN WELL: No H₂O

PURGING DATA:

METHOD: ☐ BLADDER PUMP ☒ PERISTALTIC PUMP ☐ BAILER ☐ SUB. PUMP ☐ OTHER: _____

MATERIALS: PUMP / BAILER: ☐ TEFLON ☐ STAINLESS STEEL ☐ PVC ☒ OTHER: Tygon

TUBING / ROPE: _____

☐ TEFLON ☐ POLYPROPYLENE ☐ NYLON ☒ OTHER: LDPE

PUMPING RATE: _____ ELAPSED TIME: _____ VOLUME PUMPED: _____

WAS WELL EVACUATED? ☐ YES ☐ NO NUMBER OF WELL VOLUMES PURGED: _____

TIME SERIES DATA: WELL VOLUMES _____

TEMP _____

pH _____

SPEC COND. _____

PURGING EQUIPMENT: ☒ DEDICATED ☐ PREPARED OFF-SITE ☐ FIELD CLEANED

SAMPLING DATA: Not Sampled / No H₂O

METHOD: ☐ BLADDER PUMP ☐ PERISTALTIC PUMP ☒ BAILER ☐ OTHER: _____

MATERIALS: PUMP / BAILER: ☒ TEFLON ☐ STAINLESS STEEL ☐ PVC ☐ OTHER: _____

TUBING / ROPE: _____

☐ TEFLON ☐ POLYPROPYLENE ☒ NYLON ☐ OTHER: _____

SAMPLING EQUIPMENT: ☒ DEDICATED ☐ PREPARED OFF-SITE ☐ FIELD CLEANED

METALS SAMPLE FIELD FILTERED? ☐ YES ☒ NO

METHOD: NA

PHYSICAL & CHEMICAL DATA:

APPEARANCE: ☐ CLEAR ☐ TURBID ☐ COLOR: _____

☐ CONTAINS IMMISCIBLE LIQUID ☐ OTHER: _____

FIELD DETERMINATIONS: TEMP: _____ pH: _____ SPEC. COND: _____

I CERTIFY THAT THIS SAMPLE WAS COLLECTED AND HANDLED IN ACCORDANCE WITH
APPLICABLE REGULATORY AND CORPORATE PROTOCOLS

SIGNATURE _____

10-6-98

DATE

ECKENFELDER
INC.

GROUNDWATER SAMPLING
FIELD DATA SHEET

LOCATION No. MW-23

SAMPLE No. _____

PROJECT: Meritor Supplemental Sampling

DATE: 10-6-98 TIME: 1135

CLIENT: Meritor (Rockwell) Grenada, MS

WEATHER CONDITIONS: clear

JOB No: 60380.001

AIR TEMPERATURE: 70°

PERSONNEL: S. Williams / R. Guidry

WELL DATA:

CASING, DIAMETER: 2" ☐ STAINLESS STEEL ☐ STEEL ☒ PVC ☐ TEFLON ☐ OTHER: _____

INTAKE, DIAMETER: 2" ☐ STAINLESS STEEL ☐ GALV. STEEL ☒ PVC ☐ TEFLON ☐ OPEN ROCK

STATIC WATER LEVEL: 9.82 BOTTOM DEPTH: 22.5

DATUM: ☐ TOP OF PROT. CASING ☒ TOP OF WELL CASING ☐ OTHER: _____

WELL CLEAN TO BOTTOM? ☒ YES ☐ NO WELL IN GOOD CONDITION ☒ YES ☐ NO

VOLUME OF WATER IN WELL: 2.1 gal

PURGING DATA:

METHOD: ☐ BLADDER PUMP ☒ PERISTALTIC PUMP ☐ BAILER ☐ SUB. PUMP ☐ OTHER: _____

MATERIALS: PUMP/BAILER: ☐ TEFLON ☐ STAINLESS STEEL ☐ PVC ☒ OTHER: Tygon TUBING/ROPE: ☐ TEFLON ☐ POLYPROPYLENE ☐ NYLON ☒ OTHER: LDPE

PUMPING RATE: < 0.3 gpm ELAPSED TIME: _____ VOLUME PUMPED: 6.3 gal

WAS WELL EVACUATED? ☐ YES ☒ NO NUMBER OF WELL VOLUMES PURGED: 3

TIME SERIES DATA: WELL VOLUMES 1 2 2.5 3

TEMP — — — —

pH 6.2 6.0 6.0 5.9

SPEC COND. 550 490 490 500

PURGING EQUIPMENT: ☒ DEDICATED ☐ PREPARED OFF-SITE ☐ FIELD CLEANED

SAMPLING DATA:

METHOD: ☐ BLADDER PUMP ☐ PERISTALTIC PUMP ☒ BAILER ☐ OTHER: _____

MATERIALS: PUMP/BAILER: ☒ TEFLON ☐ STAINLESS STEEL ☐ PVC ☐ OTHER: _____ TUBING/ROPE: ☐ TEFLON ☐ POLYPROPYLENE ☐ NYLON ☐ OTHER: _____

SAMPLING EQUIPMENT: ☒ DEDICATED ☐ PREPARED OFF-SITE ☐ FIELD CLEANED

METALS SAMPLE FIELD FILTERED? ☐ YES ☒ NO METHOD: NA

PHYSICAL & CHEMICAL DATA:

APPEARANCE: ☐ CLEAR ☐ TURBID ☐ COLOR: _____

☐ CONTAINS IMMISCIBLE LIQUID ☐ OTHER: _____

FIELD DETERMINATIONS: TEMP: — pH: 5.9 SPEC. COND: 500

I CERTIFY THAT THIS SAMPLE WAS COLLECTED AND HANDLED IN ACCORDANCE WITH APPLICABLE REGULATORY AND CORPORATE PROTOCOLS

SIGNATURE

10-6-98

DATE

ECKENFELDER
INC.

GROUNDWATER SAMPLING
FIELD DATA SHEET

LOCATION No. _____

RT-5

SAMPLE No. _____

PROJECT: Meritor Supplemental Sampling

DATE: 10-6-98 TIME: 1050

CLIENT: Meritor (Rockwell) Grenada, MS

WEATHER CONDITIONS: Clear

JOB No: 60380.001

AIR TEMPERATURE: 70°

PERSONNEL: S. Williams / R. Guidry

WELL DATA:

CASING, DIAMETER: 2" ☐ STAINLESS STEEL ☐ STEEL ☒ PVC ☐ TEFLON ☐ OTHER: _____

INTAKE, DIAMETER: 2" ☐ STAINLESS STEEL ☐ GALV. STEEL ☒ PVC ☐ TEFLON ☐ OPEN ROCK

STATIC WATER LEVEL: 13.05 BOTTOM DEPTH: 19.6

DATUM: ☐ TOP OF PROT. CASING ☒ TOP OF WELL CASING ☐ OTHER: _____

WELL CLEAN TO BOTTOM? ☒ YES ☐ NO WELL IN GOOD CONDITION ☒ YES ☐ NO

VOLUME OF WATER IN WELL: 1.2 gal

PURGING DATA:

METHOD: ☐ BLADDER PUMP ☒ PERISTALTIC PUMP ☐ BAILER ☐ SUB. PUMP ☐ OTHER: _____

MATERIALS: PUMP/BAILER: ☐ TEFLON ☐ STAINLESS STEEL ☐ PVC ☒ OTHER: Tygon

TUBING/ROPE: _____

☐ TEFLON
☐ POLYPROPYLENE
☐ NYLON
☒ OTHER: LDPE

PUMPING RATE: < 0.3 gpm ELAPSED TIME: _____ VOLUME PUMPED: 3.6 gal

WAS WELL EVACUATED? ☐ YES ☒ NO NUMBER OF WELL VOLUMES PURGED: 3

TIME SERIES DATA: WELL VOLUMES 1 2 3

TEMP

pH

SPEC COND.

5.9 5.9 5.9

610 650 650

PURGING EQUIPMENT: ☒ DEDICATED ☐ PREPARED OFF-SITE ☐ FIELD CLEANED

SAMPLING DATA:

METHOD: ☐ BLADDER PUMP ☐ PERISTALTIC PUMP ☒ BAILER ☐ OTHER: _____

MATERIALS: PUMP/BAILER: ☒ TEFLON ☐ STAINLESS STEEL ☐ PVC ☐ OTHER: _____

TUBING/ROPE: _____

☐ TEFLON
☐ POLYPROPYLENE
☒ NYLON
☐ OTHER: _____

SAMPLING EQUIPMENT: ☒ DEDICATED ☐ PREPARED OFF-SITE ☐ FIELD CLEANED

METALS SAMPLE FIELD FILTERED? ☐ YES ☒ NO METHOD: NA

PHYSICAL & CHEMICAL DATA:

APPEARANCE: ☐ CLEAR ☐ TURBID ☐ COLOR: _____

☐ CONTAINS IMMISCIBLE LIQUID ☐ OTHER: _____

FIELD DETERMINATIONS: TEMP: _____ pH: 5.9 SPEC. COND: 650

I CERTIFY THAT THIS SAMPLE WAS COLLECTED AND HANDLED IN ACCORDANCE WITH
APPLICABLE REGULATORY AND CORPORATE PROTOCOLS

SIGNATURE

DATE

10-6-98

ECKENFELDER INC.

GROUNDWATER SAMPLING FIELD DATA SHEET

LOCATION No. MW-4

SAMPLE No. _____

PROJECT: Meritor Supplemental Sampling

DATE: 10-5-98 TIME: 17:45

CLIENT: Meritor (Rockwell) Grenada, MS

WEATHER CONDITIONS: Ptly Cloudy brk T'storm

JOB No: 60380.001

AIR TEMPERATURE: 80°

PERSONNEL: S. Williams / R. Guidry

WELL DATA:

CASING, DIAMETER: 2" ☐ STAINLESS STEEL ☐ STEEL ☒ PVC ☐ TEFLON ☐ OTHER: _____

INTAKE, DIAMETER: 2" ☐ STAINLESS STEEL ☐ GALV. STEEL ☒ PVC ☐ TEFLON ☐ OPEN ROCK

STATIC WATER LEVEL: 15.60 BOTTOM DEPTH: 19.78

DATUM: ☐ TOP OF PROT. CASING ☒ TOP OF WELL CASING ☐ OTHER: _____

WELL CLEAN TO BOTTOM? ☒ YES ☐ NO WELL IN GOOD CONDITION ☒ YES ☐ NO

VOLUME OF WATER IN WELL: 0.7 gal

PURGING DATA:

METHOD: ☐ BLADDER PUMP ☒ PERISTALTIC PUMP ☐ BAILER ☐ SUB. PUMP ☐ OTHER: _____

MATERIALS: PUMP/BAILER: ☐ TEFLON ☐ STAINLESS STEEL ☐ PVC ☒ OTHER: Tygon TUBING/ROPE: ☐ TEFLON ☐ POLYPROPYLENE ☐ NYLON ☒ OTHER: LDPE

PUMPING RATE: < 0.3 gpm ELAPSED TIME: _____ VOLUME PUMPED: 2.2 gal

WAS WELL EVACUATED? ☐ YES ☒ NO NUMBER OF WELL VOLUMES PURGED: 3.2

TIME SERIES DATA: WELL VOLUMES 1 2 3 3.2

TEMP 5.7 5.8 5.8 5.9

pH 8.60 7.40 7.80 7.80

SPEC COND. 860 740 780 780

PURGING EQUIPMENT: ☒ DEDICATED ☐ PREPARED OFF-SITE ☐ FIELD CLEANED

SAMPLING DATA:

METHOD: ☐ BLADDER PUMP ☐ PERISTALTIC PUMP ☒ BAILER ☐ OTHER: _____

MATERIALS: PUMP/BAILER: ☒ TEFLON ☐ STAINLESS STEEL ☐ PVC ☐ OTHER: _____ TUBING/ROPE: ☐ TEFLON ☐ POLYPROPYLENE ☒ NYLON ☐ OTHER: _____

SAMPLING EQUIPMENT: ☒ DEDICATED ☐ PREPARED OFF-SITE ☐ FIELD CLEANED

METALS SAMPLE FIELD FILTERED? ☐ YES ☒ NO METHOD: NA

PHYSICAL & CHEMICAL DATA:

APPEARANCE: ☐ CLEAR ☐ TURBID ☐ COLOR: _____

☐ CONTAINS IMMISCIBLE LIQUID ☐ OTHER: _____

FIELD DETERMINATIONS: TEMP: _____ pH: 5.9 SPEC. COND: 780

I CERTIFY THAT THIS SAMPLE WAS COLLECTED AND HANDLED IN ACCORDANCE WITH APPLICABLE REGULATORY AND CORPORATE PROTOCOLS

SIGNATURE

10-5-98

DATE

ECKENFELDER
INC.

GROUNDWATER SAMPLING
FIELD DATA SHEET

LOCATION No. MW-16

SAMPLE No. _____

PROJECT: Meritor Supplemental Sampling

DATE: 10-5-98 TIME: 16:15

CLIENT: Meritor (Ratwell) Grenada, MS

WEATHER CONDITIONS: Clear w/ brief T storm

JOB No: 60380.001

AIR TEMPERATURE: 80°

PERSONNEL: S. Williams / R. Guidry

WELL DATA:

CASING, DIAMETER: 2" ☐ STAINLESS STEEL ☐ STEEL ☒ PVC ☐ TEFLON ☐ OTHER: _____

INTAKE, DIAMETER: 2" ☐ STAINLESS STEEL ☐ GALV. STEEL ☒ PVC ☐ TEFLON ☐ OPEN ROCK

STATIC WATER LEVEL: 11.62 BOTTOM DEPTH: 17.88

DATUM: ☐ TOP OF PROT. CASING ☒ TOP OF WELL CASING ☐ OTHER: _____

WELL CLEAN TO BOTTOM? ☒ YES ☐ NO WELL IN GOOD CONDITION ☒ YES ☐ NO

VOLUME OF WATER IN WELL: 1.0 gal

PURGING DATA:

METHOD: ☐ BLADDER PUMP ☒ PERISTALTIC PUMP ☐ BAILER ☐ SUB. PUMP ☐ OTHER: _____

MATERIALS: PUMP/BAILER: ☐ TEFLON ☐ STAINLESS STEEL ☐ PVC ☒ OTHER: Tygon TUBING/ROPE: ☐ TEFLON ☐ POLYPROPYLENE ☐ NYLON ☒ OTHER: LDPE

PUMPING RATE: <0.3 gpm ELAPSED TIME: _____ VOLUME PUMPED: 3 gal

WAS WELL EVACUATED? ☐ YES ☒ NO NUMBER OF WELL VOLUMES PURGED: 3

TIME SERIES DATA: WELL VOLUMES 1 2 3

TEMP

pH

SPEC COND.

5.4 5.1 5.1
1480 1360 1380

PURGING EQUIPMENT: ☒ DEDICATED ☐ PREPARED OFF-SITE ☐ FIELD CLEANED

SAMPLING DATA:

METHOD: ☐ BLADDER PUMP ☐ PERISTALTIC PUMP ☒ BAILER ☐ OTHER: _____

MATERIALS: PUMP/BAILER: ☒ TEFLON ☐ STAINLESS STEEL ☐ PVC ☐ OTHER: _____ TUBING/ROPE: ☐ TEFLON ☐ POLYPROPYLENE ☐ NYLON ☐ OTHER: _____

SAMPLING EQUIPMENT: ☒ DEDICATED ☐ PREPARED OFF-SITE ☐ FIELD CLEANED

METALS SAMPLE FIELD FILTERED? ☐ YES ☒ NO METHOD: NA

PHYSICAL & CHEMICAL DATA:

APPEARANCE: ☐ CLEAR ☐ TURBID ☒ COLOR: Brown

☐ CONTAINS IMMISCIBLE LIQUID ☐ OTHER: _____

FIELD DETERMINATIONS: TEMP: _____ pH: 5.1 SPEC. COND: 1380

I CERTIFY THAT THIS SAMPLE WAS COLLECTED AND HANDLED IN ACCORDANCE WITH
APPLICABLE REGULATORY AND CORPORATE PROTOCOLS

SIGNATURE

DATE

10-5-98

ECKENFELDER
INC.

GROUNDWATER SAMPLING
FIELD DATA SHEET

LOCATION No. MW-6

SAMPLE No. _____

PROJECT: Meritor Supplemental Sampling

DATE: 10-5-98 TIME: 1630

CLIENT: Meritor (Rockwell) Grenada, MS

WEATHER CONDITIONS: Clear w/ brief T Storm

JOB No: 60380.001

AIR TEMPERATURE: 80°

PERSONNEL: S. Williams / R. Guidry

WELL DATA:

CASING, DIAMETER: 2" ☐ STAINLESS STEEL ☐ STEEL ☒ PVC ☐ TEFLON ☐ OTHER: _____

INTAKE, DIAMETER: 2" ☐ STAINLESS STEEL ☐ GALV. STEEL ☒ PVC ☐ TEFLON ☐ OPEN ROCK

STATIC WATER LEVEL: 11.54 BOTTOM DEPTH: 18.66

DATUM: ☐ TOP OF PROT. CASING ☒ TOP OF WELL CASING ☐ OTHER: _____

WELL CLEAN TO BOTTOM? ☒ YES ☐ NO WELL IN GOOD CONDITION ☒ YES ☐ NO

VOLUME OF WATER IN WELL: 1.2 gal

PURGING DATA:

METHOD: ☐ BLADDER PUMP ☒ PERISTALTIC PUMP ☐ BAILER ☐ SUB. PUMP ☐ OTHER: _____

MATERIALS: PUMP/BAILER: ☐ TEFLON ☐ STAINLESS STEEL ☐ PVC ☒ OTHER: Tygon

TUBING/ROPE: ☐ TEFLON ☐ POLYPROPYLENE ☐ NYLON ☒ OTHER: LDPE

PUMPING RATE: < 0.3 gpm ELAPSED TIME: _____ VOLUME PUMPED: 3.6 gal

WAS WELL EVACUATED? ☐ YES ☒ NO NUMBER OF WELL VOLUMES PURGED: 3

TIME SERIES DATA: WELL VOLUMES 1 2 3

TEMP — — —

pH 5.9 5.9 5.9

SPEC COND. 600 590 590

PURGING EQUIPMENT: ☒ DEDICATED ☐ PREPARED OFF-SITE ☐ FIELD CLEANED

SAMPLING DATA:

METHOD: ☐ BLADDER PUMP ☐ PERISTALTIC PUMP ☒ BAILER ☐ OTHER: _____

MATERIALS: PUMP/BAILER: ☒ TEFLON ☐ STAINLESS STEEL ☐ PVC ☐ OTHER: _____

TUBING/ROPE: ☐ TEFLON ☐ POLYPROPYLENE ☐ NYLON ☐ OTHER: _____

SAMPLING EQUIPMENT: ☒ DEDICATED ☐ PREPARED OFF-SITE ☐ FIELD CLEANED

METALS SAMPLE FIELD FILTERED? ☐ YES ☒ NO METHOD: NA

PHYSICAL & CHEMICAL DATA:

APPEARANCE: ☐ CLEAR ☐ TURBID ☒ COLOR: gray black

☐ CONTAINS IMMISCIBLE LIQUID ☐ OTHER: _____

FIELD DETERMINATIONS: TEMP: — pH: 5.9 SPEC. COND: 590

I CERTIFY THAT THIS SAMPLE WAS COLLECTED AND HANDLED IN ACCORDANCE WITH
APPLICABLE REGULATORY AND CORPORATE PROTOCOLS

SIGNATURE

DATE

10-5-98

ECKENFELDER
INC.

GROUNDWATER SAMPLING
FIELD DATA SHEET

LOCATION No. MW-15

SAMPLE No. _____

PROJECT: Meritor Supplemental Sampling

DATE: 10-5-98 TIME: 1835

CLIENT: Meritor (Rockwell) Grenada, MS

WEATHER CONDITIONS: Partly Cloudy, brief TStorm

JOB No: 60380.001

AIR TEMPERATURE: 80°

PERSONNEL: S. Williams / R. Guidry

WELL DATA:

CASING, DIAMETER: 2" ☐ STAINLESS STEEL ☐ STEEL ☐ PVC ☐ TEFLON ☐ OTHER: _____

INTAKE, DIAMETER: 2" ☐ STAINLESS STEEL ☐ GALV. STEEL ☐ PVC ☐ TEFLON ☐ OPEN ROCK

STATIC WATER LEVEL: 16.08 BOTTOM DEPTH: 23.62

DATUM: ☐ TOP OF PROT. CASING ☒ TOP OF WELL CASING ☐ OTHER: _____

WELL CLEAN TO BOTTOM? ☒ YES ☐ NO WELL IN GOOD CONDITION ☒ YES ☐ NO

VOLUME OF WATER IN WELL: 1.2 gal

PURGING DATA:

METHOD: ☐ BLADDER PUMP ☒ PERISTALTIC PUMP ☐ BAILER ☐ SUB. PUMP ☐ OTHER: _____

MATERIALS: PUMP / BAILER: ☐ TEFLON ☐ STAINLESS STEEL ☐ PVC ☒ OTHER: Tygon TUBING / ROPE: ☐ TEFLON ☐ POLYPROPYLENE ☐ NYLON ☒ OTHER: LDPE

PUMPING RATE: < 0.3 gpm ELAPSED TIME: _____ VOLUME PUMPED: 4.2

WAS WELL EVACUATED? ☐ YES ☒ NO NUMBER OF WELL VOLUMES PURGED: 3.5

TIME SERIES DATA: WELL VOLUMES 1 2 3 3.5

TEMP	_____	_____	_____	_____
pH	<u>5.7</u>	<u>5.8</u>	<u>5.5</u>	<u>5.5</u>
SPEC COND.	<u>210</u>	<u>260</u>	<u>220</u>	<u>220</u>

PURGING EQUIPMENT: ☒ DEDICATED ☐ PREPARED OFF-SITE ☐ FIELD CLEANED

SAMPLING DATA:

METHOD: ☐ BLADDER PUMP ☐ PERISTALTIC PUMP ☒ BAILER ☐ OTHER: _____

MATERIALS: PUMP / BAILER: ☒ TEFLON ☐ STAINLESS STEEL ☐ PVC ☐ OTHER: _____ TUBING / ROPE: ☐ TEFLON ☐ POLYPROPYLENE ☒ NYLON ☐ OTHER: _____

SAMPLING EQUIPMENT: ☒ DEDICATED ☐ PREPARED OFF-SITE ☐ FIELD CLEANED

METALS SAMPLE FIELD FILTERED? ☐ YES ☒ NO METHOD: NA

PHYSICAL & CHEMICAL DATA:

APPEARANCE: ☐ CLEAR ☐ TURBID ☐ COLOR: _____

☐ CONTAINS IMMISCIBLE LIQUID ☐ OTHER: _____

FIELD DETERMINATIONS: TEMP: _____ pH: 5.5 SPEC. COND: 220

I CERTIFY THAT THIS SAMPLE WAS COLLECTED AND HANDLED IN ACCORDANCE WITH
APPLICABLE REGULATORY AND CORPORATE PROTOCOLS

[Signature]
SIGNATURE

10-5-98
DATE

ECKENFELDER
INC.

GROUNDWATER SAMPLING
FIELD DATA SHEET

LOCATION No. DW-4
SAMPLE No. _____

PROJECT: Meritor Supplemental Sampling

DATE: 10-5-98 TIME: 1845

CLIENT: Meritor (Rockwell) Grenada, MS

WEATHER CONDITIONS: Clear w/ brief T'storm

JOB No: 60380.001

AIR TEMPERATURE: 80°

PERSONNEL: S. Williams / R. Guidry

WELL DATA:

CASING, DIAMETER: 6" ☐ STAINLESS STEEL ☐ STEEL ☐ PVC ☐ TEFLON ☐ OTHER: _____

INTAKE, DIAMETER: 6" ☐ STAINLESS STEEL ☐ GALV. STEEL ☐ PVC ☐ TEFLON ☐ OPEN ROCK

STATIC WATER LEVEL: 16.34 BOTTOM DEPTH: 47.35

DATUM: ☐ TOP OF PROT. CASING ☒ TOP OF WELL CASING ☐ OTHER: _____

WELL CLEAN TO BOTTOM? ☒ YES ☐ NO WELL IN GOOD CONDITION ☒ YES ☐ NO

VOLUME OF WATER IN WELL: 20.1

PURGING DATA:

METHOD: ☐ BLADDER PUMP ☐ PERISTALTIC PUMP ☐ BAILER ☒ SUB. PUMP ☐ OTHER: _____

MATERIALS: PUMP/BAILER: ☒ TEFLON ☐ STAINLESS STEEL ☐ PVC ☐ OTHER: _____ TUBING/ROPE: ☐ TEFLON ☐ POLYPROPYLENE ☐ NYLON ☒ OTHER: LDPE

PUMPING RATE: 0.7 gpm ELAPSED TIME: 85 min VOLUME PUMPED: 62 gal

WAS WELL EVACUATED? ☐ YES ☒ NO NUMBER OF WELL VOLUMES PURGED: 3

TIME SERIES DATA: WELL VOLUMES 0 1 2 3
TEMP 23° 21° 20° 20°
pH 5.8 6.1 6.1 6.1
SPEC COND. 430 400 350 350

PURGING EQUIPMENT: ☒ DEDICATED ☐ PREPARED OFF-SITE ☐ FIELD CLEANED

SAMPLING DATA:

METHOD: ☐ BLADDER PUMP ☐ PERISTALTIC PUMP ☒ BAILER ☐ OTHER: _____

MATERIALS: PUMP/BAILER: ☒ TEFLON ☐ STAINLESS STEEL ☐ PVC ☐ OTHER: _____ TUBING/ROPE: ☐ TEFLON ☐ POLYPROPYLENE ☐ NYLON ☒ OTHER: _____

SAMPLING EQUIPMENT: ☒ DEDICATED ☐ PREPARED OFF-SITE ☐ FIELD CLEANED

METALS SAMPLE FIELD FILTERED? ☐ YES ☒ NO METHOD: NA

PHYSICAL & CHEMICAL DATA:

APPEARANCE: ☒ CLEAR ☐ TURBID ☐ COLOR: _____

☐ CONTAINS IMMISCIBLE LIQUID ☒ OTHER: yellow tint

FIELD DETERMINATIONS: TEMP: 20° pH: 6.1 SPEC. COND: 340

I CERTIFY THAT THIS SAMPLE WAS COLLECTED AND HANDLED IN ACCORDANCE WITH
APPLICABLE REGULATORY AND CORPORATE PROTOCOLS

SIGNATURE

10-5-98

DATE

OSWER Directive 9200.4-17

Chlorinated Solvents

Chlorinated solvents, such as trichloroethylene, represent another class of common contaminants that may also biodegrade under certain environmental conditions. Recent research has identified some of the mechanisms potentially responsible for degrading these solvents, furthering the development of methods for estimating biodegradation rates of these chlorinated compounds. However, the hydrologic and geochemical conditions favoring significant biodegradation of chlorinated solvents may not often occur. Because of the nature and the distribution of these compounds, natural attenuation may not be effective as a remedial option. If they are not adequately addressed through removal or containment measures, source materials can continue to contaminate groundwater for decades or even centuries. Cleanup of solvent spills is also complicated by the fact that a typical spill includes multiple contaminants, including some that are essentially non-degradable(FOOTNOTE 5) . Extremely long dissolved solvent plumes have been documented that may be due to the existence of subsurface conditions that are not conducive to natural attenuation.

OSWER Directive 9200.4-17

Inorganics

Monitored natural attenuation may, under certain conditions (*e.g.* , through sorption or oxidation-reduction reactions), effectively reduce the dissolved concentrations and/or toxic forms of inorganic contaminants in groundwater and soil. Both metals and non-metals (including radionuclides) may be attenuated by sorption(FOOTNOTE 6) reactions such as precipitation, adsorption on the surfaces of soil minerals, absorption into the matrix of soil minerals, or partitioning into organic matter. Oxidation-reduction (redox) reactions can transform the valence states of some inorganic contaminants to less soluble and thus less mobile forms (*e.g.* , hexavalent uranium to tetravalent uranium) and/or to less toxic forms (*e.g.* , hexavalent chromium to trivalent chromium). Sorption and redox reactions are the dominant mechanisms responsible for the reduction of mobility, toxicity, or bioavailability of inorganic contaminants. It is necessary to know what specific mechanism (type of sorption or redox reaction) is responsible for the attenuation of inorganics because some mechanisms are more desirable than others. For example, precipitation reactions and absorption into a soil's solid structure (*e.g.* , cesium into specific clay minerals) are generally stable, whereas surface adsorption (*e.g.* , uranium on iron-oxide minerals) and organic partitioning (complexation reactions) are more reversible. Complexation of metals or radionuclides with carrier (chelating) agents (*e.g.* , trivalent chromium with EDTA) may increase their concentrations in water and thus enhance their mobility. Changes in a contaminant's concentration, pH, redox potential, and chemical speciation may reduce a

contaminant's stability at a site and release it into the environment. Determining the existence and demonstrating the irreversibility of these mechanisms are key components of a sufficiently protective monitored natural attenuation remedy.

In addition to sorption and redox reactions, radionuclides exhibit radioactive decay and, for some, a parent-daughter radioactive decay series. For example, the dominant attenuating mechanism of tritium (a radioactive isotopic form of hydrogen with a short half-life) is radioactive decay rather than sorption. Although tritium does not generate radioactive daughter products, those generated by some radionuclides (*e.g.*, Am-241 and Np-237 from Pu-241) may be more toxic, have longer half-lives, and/or be more mobile than the parent in the decay series. It is critical that the near surface or surface soil pathways be carefully evaluated and eliminated as potential sources of radiation exposure.

Inorganic contaminants persist in the subsurface because, except for radioactive decay, they are not degraded by the other natural attenuation processes. Often, however, they may exist in forms that are less mobile, not bioavailable, and/or non-toxic. Therefore, natural attenuation of inorganic contaminants is most applicable to sites where immobilization or radioactive decay is demonstrated to be in effect and the process/mechanism is irreversible.

OSWER Directive 9200.4-17

Advantages and Disadvantages of Monitored Natural Attenuation

Monitored natural attenuation has several potential advantages and disadvantages, and its use should be carefully considered during site characterization and evaluation of remediation alternatives. **Potential advantages** of monitored natural attenuation include:

- As with any *in situ* process, generation of lesser volume of remediation wastes, reduced potential for cross-media transfer of contaminants commonly associated with *ex situ* treatment, and reduced risk of human exposure to contaminated media;
- Less intrusion as few surface structures are required;
- Potential for application to all or part of a given site, depending on site conditions and cleanup objectives;
- Use in conjunction with, or as a follow-up to, other (active) remedial measures; and
- Lower overall remediation costs than those associated with active remediation.

The **potential disadvantages** of monitored natural attenuation include:

- Longer time frames may be required to achieve remediation objectives, compared to active remediation;
- Site characterization may be more complex and costly;
- Toxicity of transformation products may exceed that of the parent compound;
- Long term monitoring will generally be necessary;
- Institutional controls may be necessary to ensure long term protectiveness;
- Potential exists for continued contamination migration, and/or cross-media transfer of contaminants;
- Hydrologic and geochemical conditions amenable to natural attenuation are likely to change over time and could result in renewed mobility of previously stabilized contaminants, adversely impacting remedial effectiveness; and
- More extensive education and outreach efforts may be required in order to gain public acceptance of monitored natural attenuation.

OSWER Directive 9200.4-17

IMPLEMENTATION

The use of monitored natural attenuation is not new in OSWER programs. For example, in the Superfund program, selection of natural attenuation as an element in a site's groundwater remedy goes as far back as 1985. Use of monitored natural attenuation in OSWER programs has continued since that time, slowly increasing with greater program experience and scientific understanding of the processes involved. Recent advances in the scientific understanding of the processes contributing to natural attenuation have resulted in a heightened interest in this approach as a potential means of achieving soil and groundwater cleanup objectives. However, complete reliance on monitored natural attenuation is appropriate only in a limited set of circumstances at contaminated sites. The sections which follow seek to clarify OSWER program policies regarding the use of monitored natural attenuation. Topics addressed include site characterization; the types of sites where monitored natural attenuation may be appropriate; reasonable remediation time frames; the importance of source control; performance monitoring; and contingency remedies where monitored natural attenuation will be employed.

OSWER Directive 9200.4-17

Role of Monitored Natural Attenuation in OSWER Remediation Programs

Under OSWER programs, remedies selected for contaminated media (such as contaminated soil and groundwater) must protect human health and the environment. Remedies may achieve this level of protection using a variety of methods, including treatment, containment, engineering controls, and other means identified during the remedy selection process.

The regulatory and policy frameworks for corrective actions under the UST, RCRA, and Superfund programs have been established to implement their respective statutory mandates and to promote the selection of technically defensible, nationally consistent, and cost effective solutions for the cleanup of contaminated media. EPA recognizes that monitored natural attenuation may be an appropriate remediation option for contaminated soil and groundwater under certain circumstances. However, determining the appropriate mix of remediation methods at a given site, including when and how to use monitored natural attenuation, can be a complex process. Therefore, monitored natural attenuation should be carefully evaluated along with other viable remedial approaches or technologies (including innovative technologies) within the applicable remedy selection framework. **Monitored natural attenuation should not be considered a default or presumptive remedy at any contaminated site.**

Each OSWER program has developed regulations and policies to address the particular types of contaminants and facilities within its purview (FOOTNOTE 7). Although there are differences among these programs, they share several key principles that should generally be considered during selection of remedial measures, including:

- Source control actions should use treatment to address "principal threat" wastes (or products) wherever practicable, and engineering controls such as containment for waste (or products) that pose a relatively low long-term threat, or where treatment is impracticable.(FOOTNOTE 8)
- Contaminated groundwaters should be returned to "their beneficial uses (FOOTNOTE 9) wherever practicable, within a time frame that is reasonable given the particular circumstances of the site." When restoration of groundwater is not practicable, EPA "expects to prevent further migration of the plume, prevent exposure to the contaminated groundwater, and evaluate further risk reduction" (which may be appropriate).(FOOTNOTE 10)
- Contaminated soil should be remediated to achieve an acceptable level of risk to human and environmental receptors, and to prevent any transfer of contaminants to other media (e.g., surface or groundwater, air, sediments) that would result in an unacceptable risk or exceed required cleanup levels.

Consideration or selection of monitored natural attenuation as a remedy or remedy component does not in any way change or displace these (or other) remedy selection principles. Nor does use of monitored natural attenuation diminish EPA's or the regulated party's responsibility to achieve protectiveness or to satisfy long-term site cleanup objectives. **Monitored**

natural attenuation is an appropriate remediation method only where its use will be protective of human health and the environment and it will be capable of achieving site-specific remediation objectives within a time frame that is reasonable compared to other alternatives. The effectiveness of monitored natural attenuation in both near-term and long-term time frames should be demonstrated to EPA (or other regulatory authority) through: 1) sound technical analysis which provides confidence in natural attenuation's ability to achieve remediation objectives; 2) performance monitoring; and 3) backup or contingency remedies where appropriate. **In summary, use of monitored natural attenuation does not imply that EPA or the responsible parties are "walking away" from the cleanup or financial responsibility obligations at a site.**

It also should be emphasized that the selection of monitored natural attenuation as a remedy does not imply that active remediation measures are infeasible, or are "technically impracticable." Technical impracticability (TI) determinations, which EPA makes based on the inability to achieve required cleanup levels using available remedial technologies and approaches, are used to justify a change in the remediation objectives at Superfund and RCRA sites (USEPA, 1993a). A TI determination does not imply that there will be no active remediation at the site, nor that monitored natural attenuation will be used at the site. Rather, a TI determination simply indicates that the cleanup levels and objectives which would otherwise be required cannot practicably be attained within a reasonable time frame using available remediation technologies. In such cases, an alternative cleanup strategy that is fully protective of human health and the environment must be identified. Such an alternative strategy may still include engineered remediation components, such as containment for an area contaminated with dense non-aqueous phase liquids (DNAPL), in addition to approaches intended to restore to beneficial uses the portion of the plume with dissolved contaminants. Several remedial approaches could be appropriate to address the dissolved plume, one of which could be monitored natural attenuation under suitable conditions. However, the evaluation of natural attenuation processes and the decision to rely upon monitored natural attenuation for the dissolved plume should be distinct from the recognition that restoration of a portion of the plume is technically impracticable (*i.e.*, monitored natural attenuation should not be viewed as a direct or presumptive outcome of a technical impracticability determination.)

OSWER Directive 9200.4-17

Demonstrating the Efficacy of Natural Attenuation through Site Characterization

Decisions to employ monitored natural attenuation as a remedy or remedy component should be thoroughly and adequately supported with site-specific characterization data and analysis. In general, the level of site characterization necessary to support a comprehensive evaluation of natural attenuation is more detailed than that needed to support active remediation. Site characterizations for natural attenuation generally warrant a quantitative understanding of source mass; groundwater flow; contaminant phase distribution and partitioning between soil, groundwater, and soil gas; rates of biological and non-biological transformation; and an understanding of how all of these factors are likely to vary with time. This information is generally

necessary since contaminant behavior is governed by dynamic processes which must be well understood before natural attenuation can be appropriately applied at a site. Demonstrating the efficacy of this remediation approach likely will require analytical or numerical simulation of complex attenuation processes. Such analyses, which are critical to demonstrate natural attenuation's ability to meet remedial action objectives, generally require a detailed conceptual site model as a foundation(FOOTNOTE 11) .

Site characterization should include collecting data to define (in three spatial dimensions over time) the nature and distribution of contamination sources as well as the extent of the groundwater plume and its potential impacts on receptors. However, where monitored natural attenuation will be considered as a remedial approach, certain aspects of site characterization may require more detail or additional elements. For example, to assess the contributions of sorption, dilution, and dispersion to natural attenuation of contaminated groundwater, a very detailed understanding of aquifer hydraulics, recharge and discharge areas and volumes, and chemical properties is required. Where biodegradation will be assessed, characterization also should include evaluation of the nutrients and electron donors and acceptors present in the groundwater, the concentrations of co-metabolites and metabolic by-products, and perhaps specific analyses to identify the microbial populations present. The findings of these, and any other analyses pertinent to characterizing natural attenuation processes, should be incorporated into the conceptual model of contaminant fate and transport developed for the site.

Monitored natural attenuation may not be appropriate as a remedial option at many sites for technological or economic reasons. For example, in some complex geologic systems, technological limitations may preclude adequate monitoring of a natural attenuation remedy to ensure with a high degree of certainty that potential receptors will not be impacted. This situation typically occurs in many karstic, structured, and/or fractured rock aquifers where groundwater moves preferentially through discrete channels (*e.g.* , solution channels, foliations, fractures, joints). The direction of groundwater flow through such heterogeneous (and often anisotropic) materials can not be predicted directly from the hydraulic gradient, and existing techniques may not be capable of identifying the channels that carry contaminated groundwater through the subsurface. Monitored natural attenuation will not generally be appropriate where site complexities preclude adequate monitoring. Although in some situations it may be technically feasible to monitor the progress of natural attenuation, the cost of site characterization and long-term monitoring required for the implementation of monitored natural attenuation is high compared to the cost of other remedial alternatives. Under such circumstances, natural attenuation would not necessarily be the low-cost alternative.

A related consideration for site characterization is how other remedial activities at the site could affect natural attenuation. For example, the capping of contaminated soil could alter both the type of contaminants leached to groundwater, as well as their rate of transport and degradation. Therefore, the impacts of any ongoing or proposed remedial actions should be factored into the analysis of natural attenuation's effectiveness. When considering source containment/treatment together with natural attenuation of chlorinated solvents, the potential for cutting off sources of organic carbon (which are critical to biodegradation of the solvents) should be carefully evaluated.

Once the site characterization data have been collected and a conceptual model developed, the next step is to evaluate the efficacy of monitored natural attenuation as a remedial approach. Three types of site-specific information or "evidence" should be used in such an evaluation:

1. Historical groundwater and/or soil chemistry data that demonstrate a clear and meaningful trend(FOOTNOTE 12) of decreasing contaminant mass and/or concentration over time at appropriate monitoring or sampling points. (In the case of a groundwater plume, decreasing concentrations should not be solely the result of plume migration. In the case of inorganic contaminants, the primary attenuating mechanism should also be understood.);
2. Hydrogeologic and geochemical data that can be used to demonstrate indirectly the type(s) of natural attenuation processes active at the site, and the rate at which such processes will reduce contaminant concentrations to required levels. For example, characterization data may be used to quantify the rates of contaminant sorption, dilution, or volatilization, or to demonstrate and quantify the rates of biological degradation processes occurring at the site;
3. Data from field or microcosm studies (conducted in or with actual contaminated site media) which directly demonstrate the occurrence of a particular natural attenuation process at the site and its ability to degrade the contaminants of concern (typically used to demonstrate biological degradation processes only).

Unless EPA or the implementing state agency determines that historical data (Number 1 above) are of sufficient quality and duration to support a decision to use monitored natural attenuation, EPA expects that data characterizing the nature and rates of natural attenuation processes at the site (Number 2 above) should be provided. Where the latter are also inadequate or inconclusive, data from microcosm studies (Number 3 above) may also be necessary. In general, more supporting information may be required to demonstrate the efficacy of monitored natural attenuation at those sites with contaminants which do not readily degrade through biological processes (*e.g.* , most non-petroleum compounds, inorganics), at sites with contaminants that transform into more toxic and/or mobile forms than the parent contaminant, or at sites where monitoring has been performed for a relatively short period of time. The amount and type of information needed for such a demonstration will depend upon a number of site-specific factors, such as the size and nature of the contamination problem, the proximity of receptors and the potential risk to those receptors, and other physical characteristics of the environmental setting (*e.g.* , hydrogeology, ground cover, or climatic conditions).

Note that those parties responsible for site characterization and remediation should ensure that all data and analyses needed to demonstrate the efficacy of monitored natural attenuation are collected and evaluated by capable technical specialists with expertise in the relevant sciences. Further, EPA expects that the results will be provided in a timely manner to EPA or to the state implementing agency for evaluation and approval.

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Sites Where Monitored Natural Attenuation May Be Appropriate

Monitored natural attenuation is appropriate as a remedial approach only where it can be demonstrated capable of achieving a site's remedial objectives within a time frame that is reasonable compared to that offered by other methods and where it meets the applicable remedy selection criteria for the particular OSWER program. EPA expects that monitored natural attenuation will be most appropriate when used in conjunction with active remediation measures (*e.g.*, source control), or as a follow-up to active remediation measures that have already been implemented.

In determining whether monitored natural attenuation is an appropriate remedy for soil or groundwater at given site, EPA or other regulatory authorities should consider the following:

- Whether the contaminants present in soil or groundwater can be effectively remediated by natural attenuation processes;
- Whether the resulting transformation products present a greater risk than do the parent contaminants;
- The nature and distribution of sources of contamination and whether these sources have been or can be adequately controlled;
- Whether the plume is relatively stable or is still migrating and the potential for environmental conditions to change over time;
- The impact of existing and proposed active remediation measures upon the monitored natural attenuation component of the remedy;
- Whether drinking water supplies, other groundwaters, surface waters, ecosystems, sediments, air, or other environmental resources could be adversely impacted as a consequence of selecting monitored natural attenuation as the remediation option;
- Whether the estimated time frame of remediation is reasonable (see below) compared to time frames required for other more active methods (including the anticipated effectiveness of various remedial approaches on different portions of the contaminated soil and/or groundwater);
- Current and projected demand for the affected aquifer over the time period that the remedy will remain in effect (including the availability of other water supplies and the loss of availability of other groundwater resources due to contamination from other sources); and
- Whether reliable site-specific vehicles for implementing institutional controls (*i.e.*, zoning ordinances) are available, and if an institution

responsible for their monitoring and enforcement can be identified.

For example, evaluation of a given site may determine that, once the source area and higher concentration portions of the plume are effectively contained or remediated, lower concentration portions of the plume could achieve cleanup standards within a few decades through monitored natural attenuation, if this time frame is comparable to those of the more aggressive methods evaluated for this site. Also, monitored natural attenuation would more likely be appropriate if the plume is not expanding, nor threatening downgradient wells or surface water bodies, and where ample potable water supplies are available. The remedy for this site could include source control, a pump-and-treat system to mitigate only the highly- contaminated plume areas, and monitored natural attenuation in the lower concentration portions of the plume. In combination, these methods would maximize groundwater restored to beneficial use in a time frame consistent with future demand on the aquifer, while utilizing natural attenuation processes to reduce the reliance on active remediation methods (and reduce cost).

Of the above factors, the most important considerations regarding the suitability of monitored natural attenuation as a remedy include whether the groundwater contaminant plume is growing, stable, or shrinking, and any risks posed to human and environmental receptors by the contamination. **Monitored natural attenuation should not be used where such an approach would result in significant contaminant migration or unacceptable impacts to receptors.** Therefore, sites where the contaminant plumes are no longer increasing in size, or are shrinking in size, would be the most appropriate candidates for monitored natural attenuation remedies.

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Reasonableness of Remediation Time Frame

The longer remediation time frames typically associated with monitored natural attenuation should be compatible with site-specific land and groundwater use scenarios. Remediation time frames generally should be estimated for all remedy alternatives undergoing detailed analysis, including monitored natural attenuation(FOOTNOTE 13) . Decisions regarding the "reasonableness" of the remediation time frame for any given remedy alternative should then be evaluated on a site-specific basis. While it is expected that monitored natural attenuation may require somewhat longer to achieve remediation objectives than would active remediation, the overall remediation time frame for a remedy which relies in whole or in part on monitored natural attenuation should not be excessive compared to the other remedies considered. Furthermore, subsurface conditions and plume stability can change over the extended timeframes that are necessary for monitored natural attenuation.

Defining a reasonable time frame is a complex and site-specific decision. Factors that should be considered when evaluating the length of time appropriate for remediation include:

- Classification of the affected resource (e.g. , drinking water source,

agricultural water source) and value of the resource(FOOTNOTE 14) ;

- Relative time frame in which the affected portions of the aquifer might be needed for future water supply (including the availability of alternate supplies);
- **Uncertainties** regarding the mass of contaminants in the subsurface and predictive analyses (*e.g.* , remediation time frame, timing of future demand, and travel time for contaminants to reach points of exposure appropriate for the site);
- Reliability of monitoring and of institutional controls over long time periods;
- Public acceptance of the extended time for remediation; and
- Provisions by the responsible party for adequate funding of monitoring and performance evaluation over the period required for remediation.

Finally, individual states may provide information and guidance relevant to many of the factors discussed above as part of a Comprehensive State Groundwater Protection Program (CSGWPP). (See USEPA, 1992a) Where a CSGWPP has been developed, it should be consulted for groundwater resource classification and other information relevant to determining required cleanup levels and the urgency of the need for the groundwater. Also, EPA remediation programs generally should defer to state determinations of current and future groundwater uses, when based on an EPA-endorsed CSGWPP that has provisions for site-specific decisions (USEPA, 1997b).

Thus, EPA or other regulatory authorities should consider a number of factors when evaluating reasonable time frames for monitored natural attenuation at a given site. These factors, on the whole, should allow the regulatory agency to determine whether a natural attenuation remedy (including institutional controls where applicable) will fully protect potential human and environmental receptors, and whether the site remediation objectives and the time needed to meet them are consistent with the regulatory expectation that contaminated groundwaters will be returned to beneficial uses within a reasonable time frame. When these conditions cannot be met using monitored natural attenuation, a remedial alternative that does meet these expectations should be selected instead.

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Remediation of Contamination Sources and Highly Contaminated Areas

The need for control measures for contamination sources and other highly contaminated areas should be evaluated as part of the remedy decision process at all sites, particularly where monitored natural attenuation is under consideration as the remedy or as a remedy component. Source control measures include removal, treatment, or containment measures (*e.g.* ,

physical or hydraulic control of areas of the plume in which NAPLs are present in the subsurface). EPA prefers remedial options which remove or treat contaminant sources when such options are technically feasible.

Contaminant sources which are not adequately addressed complicate the long-term cleanup effort. For example, following free product recovery, residual contamination from a petroleum fuel spill may continue to leach significant quantities of contaminants into the groundwater. Such a lingering source can unacceptably extend the time necessary to reach remedial objectives. This leaching can occur even while contaminants are being naturally attenuated in other parts of the plume. If the rate of attenuation is lower than the rate of replenishment of contaminants to the groundwater, the plume can continue to expand and threaten downgradient receptors.

Control of source materials is the most effective means of ensuring the timely attainment of remediation objectives. EPA, therefore, expects that source control measures will be evaluated for **all** contaminated sites and that source control measures will be taken at most sites where practicable.



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Performance Monitoring

Performance monitoring to evaluate remedy effectiveness and to ensure protection of human health and the environment is a critical element of all response actions. Performance monitoring is of even greater importance for monitored natural attenuation than for other types of remedies due to the longer remediation time frames, potential for ongoing contaminant migration, and other uncertainties associated with using monitored natural attenuation. This emphasis is underscored by EPA's reference to "monitored natural attenuation".

The monitoring program developed for each site should specify the location, frequency, and type of samples and measurements necessary to evaluate remedy performance as well as define the anticipated performance objectives of the remedy. In addition, all monitoring programs should be designed to accomplish the following:

- Demonstrate that natural attenuation is occurring according to expectations;
- Identify any potentially toxic transformation products resulting from biodegradation;
- Determine if a plume is expanding (either downgradient, laterally or vertically);
- Ensure no impact to downgradient receptors;
- Detect new releases of contaminants to the environment that could impact the effectiveness of the natural attenuation remedy;

- Demonstrate the efficacy of institutional controls that were put in place to protect potential receptors;
- Detect changes in environmental conditions (*e.g.* , hydrogeologic, geochemical, microbiological, or other changes) that may reduce the efficacy of any of the natural attenuation processes(FOOTNOTE 15) ; and
- Verify attainment of cleanup objectives.

Performance monitoring should continue as long as contamination remains above required cleanup levels. Typically, monitoring is continued for a specified period (*e.g.* , one to three years) after cleanup levels have been achieved to ensure that concentration levels are stable and remain below target levels. The institutional and financial mechanisms for maintaining the monitoring program should be clearly established in the remedy decision or other site documents, as appropriate.

Details of the monitoring program should be provided to EPA or the State implementing agency as part of any proposed monitored natural attenuation remedy. Further information on the types of data useful for monitoring natural attenuation performance can be found in the ORD publications (*e.g.* , USEPA, 1997a, USEPA, 1994a) listed in the "References Cited" section of this Directive. Also, USEPA (1994b) published a detailed document on collection and evaluation of performance monitoring data for pump-and-treat remediation systems.

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Contingency Remedies

A contingency remedy is a cleanup technology or approach specified in the site remedy decision document that functions as a "backup" remedy in the event that the "selected" remedy fails to perform as anticipated. A contingency remedy may specify a technology (or technologies) that is (are) different from the selected remedy, or it may simply call for modification and enhancement of the selected technology, if needed. Contingency remedies should generally be flexible allowing for the incorporation of new information about site risks and technologies.

Contingency remedies are not new to OSWER programs. Contingency remedies should be employed where the selected technology is not proven for the specific site application, where there is significant uncertainty regarding the nature and extent of contamination at the time the remedy is selected, or where there is uncertainty regarding whether a proven technology will perform as anticipated under the particular circumstances of the site.

It is also recommended that one or more criteria ("triggers") be established, as appropriate, in the remedy decision document that will signal unacceptable performance of the selected remedy and indicate when to

implement contingency measures. Such criteria might include the following:

- Contaminant concentrations in soil or groundwater at specified locations exhibit an increasing trend;
- Near-source wells exhibit large concentration increases indicative of a new or renewed release;
- Contaminants are identified in sentry/sentinel wells located outside of the original plume boundary, indicating renewed contaminant migration;
- Contaminant concentrations are not decreasing at a sufficiently rapid rate to meet the remediation objectives; and
- Changes in land and/or groundwater use will adversely affect the protectiveness of the monitored natural attenuation remedy.

In establishing triggers or contingency remedies, however, care is needed to ensure that sampling variability or seasonal fluctuations do not set off a trigger inappropriately. For example, an anomalous spike in dissolved concentration(s) at a well(s), which may set off a trigger, might not be a true indication of a change in trend.

EPA recommends that remedies employing monitored natural attenuation be evaluated to determine the need for including one or more contingency measures that would be capable of achieving remediation objectives. EPA believes that a contingency measure may be particularly appropriate for a monitored natural attenuation remedy which has been selected based primarily on predictive analysis (second and third lines of evidence discussed previously) as compared to natural attenuation remedies based on historical trends of actual monitoring data (first line of evidence).

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SUMMARY

The use of monitored natural attenuation does not signify a change in OSWER's remediation objectives; monitored natural attenuation should be selected only where it will be fully protective of human health and the environment. EPA does not view monitored natural attenuation to be a "no action" remedy, but rather considers it to be a means of addressing contamination under a limited set of site circumstances where its use meets the applicable statutory and regulatory requirements. Monitored natural attenuation is not a "presumptive" or "default" remediation alternative, but rather should be evaluated and compared to other viable remediation methods (including innovative technologies) during the study phases leading to the selection of a remedy. The decision to implement monitored natural attenuation should include a comprehensive site characterization, risk assessment where appropriate, and measures to control sources. Also, monitored natural attenuation should not be used where such an approach

would result in significant contaminant migration or unacceptable impacts to receptors and other environmental resources. In addition, the progress of natural attenuation towards a site's remediation objectives should be carefully monitored and compared with expectations to ensure that it will meet site remediation objectives within a time frame that is reasonable compared to time frames associated with other methods. Where monitored natural attenuation's ability to meet these expectations is uncertain and based predominantly on predictive analyses, decision-makers should incorporate contingency measures into the remedy.

EPA is confident that monitored natural attenuation will be, at many sites, a reasonable and protective component of a broader remedial strategy. However, EPA believes that there will be many other sites where uncertainties too great or a need for a more rapid remediation will preclude the use of monitored natural attenuation as a stand-alone remedy. This Directive should help promote consistency in how monitored natural attenuation remedies are proposed, evaluated, and approved.

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OTHER SOURCES OF INFORMATION

USEPA Internet Web Sites

<http://www.epa.gov/ORD/WebPubs/bioremed/>
Office of Research and Development, information on passive and active bioremediation

<http://www.epa.gov/ada/kerrlab.html>
Office of Research and Development, R.S. Kerr Environmental Research

Laboratory

<http://www.epa.gov/OUST/cat/natatt.htm>

Office of Underground Storage Tanks, information on natural attenuation

<http://www.epa.gov/swerffrr/chlorine.htm>

Federal Facilities Restoration and Reuse Office, fact sheet on natural attenuation of chlorinated solvents

<http://www.epa.gov/swerffrr/petrol.htm>

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<http://www.epa.gov/epaoswer/hazwaste/ca/sub122-1.txt>

Office of Solid Waste, information on RCRA Subpart S

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Office of Outreach Programs, Special Projects, and Initiatives, information on Brownfields

Other Internet Web Sites



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Technology Innovation Office, information on hazardous site cleanups

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FOOTNOTES

¹ Environmental resources to be protected include groundwater, drinking water supplies, surface waters, ecosystems and other media (air, soil and sediments) that could be impacted from site contamination. ([Return to text](#))

² In this Directive, remediation objectives are the overall objectives that remedial actions are intended to accomplish and are not the same as chemical-specific cleanup levels. Remediation objectives could include preventing exposure to contaminants, minimizing further migration of contaminants from source areas, minimizing further migration of the groundwater contaminant plume, reducing contamination in soil or groundwater to specified cleanup levels appropriate for current or potential future uses, or other objectives. ([Return to text](#))

³ The term "transformation products" in the Directive includes biotically and abiotically formed products described above (e.g., TCE, DCE, vinyl chloride), decay chain daughter products from radioactive decay, and inorganic elements that become methylated compounds (e.g., methyl mercury) in soil and sediment. ([Return to text](#))

⁴ The term "institutional controls" refers to non-engineering measures

usually, but not always, legal controls intended to affect human activities in such a way as to prevent or reduce exposure to hazardous substances. Examples of institutional controls cited in the National Contingency Plan (USEPA, 1990a, p.8706) include land and resource (*e.g.* , water) use and deed restrictions, well-drilling prohibitions, building permits, well use advisories, and deed notices. ([Return to text](#))

⁵ For example, 1,4-dioxane, which is used as a stabilizer for some chlorinated solvents, is more highly toxic, less likely to sorb to aquifer solids, and less biodegradable than are other solvents under the same environmental conditions. ([Return to text](#))

⁶When a contaminant is associated with a solid phase, it is usually not known if the contaminant is precipitated as a three-dimensional molecular coating on the surface of the solid, adsorbed onto the surface of the solid, absorbed into the structure of the solid, or partitioned into organic matter. "Sorption" will be used in this Directive to describe, in a generic sense (*i.e.* , without regard to the precise mechanism) the partitioning of aqueous phase constituents to a solid phase. ([Return to text](#))

⁷Existing program guidance and policy regarding monitored natural attenuation can be obtained from the following sources: For Superfund, see "Guidance on Remedial Actions for Contaminated Groundwater at Superfund Sites," (USEPA, 1988a; pp. 5-7 and 5-8); the Preamble to the 1990 National Contingency Plan (USEPA, 1990a, pp.8733-34); and "Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance" (USEPA, 1996a; p. 18). For the RCRA program, see the Subpart S Proposed Rule (USEPA, 1990b, pp.30825 and 30829), and the Advance Notice of Proposed Rulemaking (USEPA, 1996b, pp.19451-52). For the UST program, refer to Chapter IX in "How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers;" (USEPA, 1995a). ([Return to text](#))

⁸Principal threat wastes are those source materials (*e.g.* ,non-aqueous phase liquids [NAPL], saturated soils) that are highly toxic or highly mobile that generally cannot be reliably contained (USEPA, 1991). Low level threat wastes are source materials that can be reliably contained or that would pose only a low risk in the event of exposure. Contaminated groundwater is neither a principal nor a low-level threat waste. ([Return to text](#))

⁹Beneficial uses of groundwater could include uses for which water quality standards have been promulgated, such as a drinking water supply, or as a source of recharge to surface water, or other uses. These or other types of beneficial uses may be identified as part of a Comprehensive State Groundwater Protection Program (CSGWPP). For more information on CSGWPPs, see [USEPA, 1992a](#) and [USEPA, 1997b](#), or contact your state implementing agency. ([Return to text](#))

¹⁰This is a general expectation for remedy selection in the Superfund program, as stated in the National Contingency Plan (USEPA, 1990a, §300.430 (a)(1)(iii)(F)). The NCP Preamble also specifies that cleanup levels appropriate for the expected beneficial use (*e.g.* , MCLs for drinking water) "should generally be attained throughout the contaminated plume, or at and

beyond the edge of the waste management area when waste is left in place."
(Return to text)

¹¹A conceptual site model is a three-dimensional representation that conveys what is known or suspected about contamination sources, release mechanisms, and the transport and fate of those contaminants. The conceptual model provides the basis for assessing potential remedial technologies at the site. "Conceptual site model" is not synonymous with "computer model;" however, a computer model may be helpful for understanding and visualizing current site conditions or for predictive simulations of potential future conditions. Computer models, which simulate site processes mathematically, should in turn be based upon sound conceptual site models to provide meaningful information. Computer models typically require a lot of data, and the quality of the output from computer models is directly related to the quality of the input data. Because of the complexity of natural systems, models necessarily rely on simplifying assumptions that may or may not accurately represent the dynamics of the natural system. Calibration and sensitivity analyses are important steps in appropriate use of models. Even so, the results of computer models should be carefully interpreted and continuously verified with adequate field data. Numerous EPA references on models are listed in the "Additional References" section at the end of this Directive. (Return to text)

¹²For guidance on the statistical analysis of environmental data, please see USEPA, 1989 and USEPA, 1992b, listed in the "References Cited" section at the end of this Directive. (Return to text)

¹³EPA recognizes that predictions of remediation time frames may involve significant uncertainty; however, such predictions are very useful when comparing two or more remedy alternatives. (Return to text)

¹⁴In determining whether an extended remediation time frame may be appropriate for the site, EPA and other regulatory authorities should consider state groundwater resource classifications, priorities and/or valuations where available, in addition to relevant federal guidelines. (Return to text)

¹⁵Detection of changes will depend on the proper siting and construction of monitoring wells/points. Although the siting of monitoring wells is a concern for any remediation technology, it is of even greater concern with monitored natural attenuation because of the lack of engineering controls to control contaminant migration. (Return to text)



[Information on OSWER Directive 9200.4-17]

URL: http://www.epa.gov/OUST/directiv/9200_417.htm

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